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Space Applications Institute

Annual Report 96

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Scientific & Technical Support	69
Administrative Support	17
Scientific Visitors	6
PhD/Post Doc Grantholders	23
Student Visitors	23
Total SAI Staff	138

Executive summary

The Space Applications Institute (SAI) has the objective of the generation of relevant, timely and accurate information from remote sensing and Space systems. The biosphere, lithosphere, atmosphere and hydrosphere are all considered in this context, with work ranging from fundamental research to the operational use of remote sensing.

This involves work supporting the sectorial policies of the European Union concerning agriculture, forestry, environment, aid to development and regional aid, and work to promote, disseminate and support remote sensing applications and services in the Earth Observation industry, research Institutions and government organisations.

These tasks reflect the Institute's neutrality, pan-European perspective and compliance with the subsidiarity principle.

The Institute's work in 1996 was spread over four domains. These are:

- Institutional Research, the Specific Programme (where research themes, defined and approved by the European Union's Member States via the Joint Research Centre's Governing Board are addressed),
- Institutional Support (where SAI provides scientific and technical support to the sectorial policies of the Commission. This involves research on behalf of various Directorates General (DG) where the objectives are specifically set by the DGs),
- Competitive Activities. In the Fourth Framework Programme SAI, along with all JRC Institutes, participated in the EC's Shared Cost Actions, Concerted Actions and Competitive Support to the Commission, in addition to non framework programme initiatives and work for third parties,
- Exploratory Research (this is a percentage of the Specific Programme funds used to explore research themes which show promise for future applications, but are not currently contained in the Specific Programme).

The 1996 programme of Work

To meet SAI's institutional role and comply with the subsidiarity principle, the work is mainly accomplished through development of large applications projects. Examples include the Centre for Earth Observation (CEO), Monitoring of Agriculture with Remote Sensing (MARS), Tropical Forest Monitoring (TREES), wild fire monitoring (FIRE), management and development of marine environmental data sets (OCEAN and OCTOPUS) and the mapping and inventory of European temperate forests (FIRS).

1996 also saw the first year in which the Institute addressed the synergistic use of remote sensing with the other key Space technologies of satellite telecommunications and satellite navigation.

In 1996 too the SAI consolidated its involvement in competitive work. In partnership with European entities the Institute submitted 19 proposals in six different programmatic areas of the fourth framework programme. The Institute was successful in 10 of these proposals. In addition, the Institute continued Competitive Support to the Commission concerning the TREES II project for DGXI. The Institute also secured major involvement in the non framework programme project PHARE, and continued to develop work for third parties.

The work of these large applications projects, and the research required to generate new applications of remote sensing, is performed by the Institute's six Units. The Institute organigramme is shown in page 4.

Agricultural Information Systems

The Agricultural Information Systems unit (AIS) focuses on the development of remote sensing techniques for the monitoring of Europe's agricultural land. Much of this work is on behalf of Directorate General VI (Agriculture) and the European Statistical Office (EUROSTAT). In 1996 the Unit launched and managed a new activity, the MERA (MARS and Environmental Related Applications) project in Central Europe in support to DGI (External Relations).

Activities concerning natural hazards saw the beginning of pilot projects on forest fires, floods and droughts during the year. In addition close co-ordination with other European initiatives in this field were maintained. For example, in July 1996 a workshop on Space Techniques and Major Hazard´s was organised together with the Council of Europe - Secretary of the Open Partial Agreement on Major Hazards, the European Space Agency - Directorate on Strategy, and the European Commission - DG XII / D4.
Two other activities gained wider recognition in 1996. Support to the European Environmental Agency in the field of land cover change was provided through AIS's research co-ordination contribution to the European Land Cover Topic Centre. The European Soil Bureau expanded its work harmonising the soils data base and general mapping activities relevant to Europe.

Linked to these are other environmental developments, such as a specific project which aims at defining and mapping the changes in the land part of the coastal zones. Throughout the year too the unit enjoyed success in obtaining resources under the competitive scheme requested by the Member States.

Environmental Mapping and Modelling

The Environmental Mapping and Modelling Unit (EMAP) concentrates on the mapping and monitoring of various European landscape components. During 1996 activities concentrated on soil and vegetation monitoring. Two main themes were addressed: (a) mapping and monitoring the main permanent large ecosystems of Europe, i.e. forest and natural grassland, and (b) developing monitoring and protection methods based on the combination (through GIS) of remote sensing and dynamic models, applied to ecologically sensitive regions, such as the Mediterranean basin. The FIRS project (Forest Information from Remote Sensing) and land degradation studies, including landslides were the principle foci for this work. The development of an environmental spectral library concept and studies aiming at the definition of regional scale desertification indicators and application of spectral mixture analysis methods to diversified landscapes are among the most important results for the year. The forest component of the MERA Project applying the FIRS methodology was also completed for the Czech Republic, Hungary, Poland, Romania and Slovakia.

The Unit also continued the development of advanced methods of image and data processing. These activities noticeably expanded in 1996 to fulfil commitments connected to shared-cost and support to the Commission actions. These dealt with neural computing and the development of a European GIS research strategy.

Third party work for the Sicily Region was also completed on time. Clear results on soil erosion modelling and coastal evolution monitoring were obtained through a combined GIS, remote sensing and modelling approach.

Marine Environment

The work of the Marine Environment (ME) Unit falls into two closely linked areas. Firstly the unit concentrates on the development, implementation and validation of methodologies for derivation of ocean colour and sea surface measurements from remotely sensed data. Secondly ME is developing hydrodynamic models that, assimilating the remotely sensed measurements, can be used for the study of different oceanic processes and contribute to global models.

In 1996, a new era of ocean colour measurement from Space started with the successful launch of two new sensors; the Modular Optoelectronic Scanners (MOS), German imaging spectrometers operating on board the PRIRODA-module of the Russian space station MIR, and on the Indian satellite IRS-P3 and the Japanese Ocean Colour and Temperature Sensor (OCTS). The ME Unit invested considerable effort in dealing with the new data, meeting new challenges and profiting from the new possibilities for monitoring and management of the marine environment.

Applied research demonstrated that environmental parameters cannot be neglected in predictive models of fish recruitment in the coastal area. The Unit also started work on operational studies using satellite data for the management of the coastal zone.

Fundamental research demonstrated the potential of remotely sensed observations for reconstructing flow structures in ocean circulation, and thus improve simulation computations.

The Unit´s web server was also greatly enhanced. The server, URL: http://me-www.jrc.it/, provides links to relevant information and publications as well as allowing remote users to browse the Unit's comprehensive Ocean Colour and Sea Surface Temperature archives.

Monitoring of Tropical Vegetation

The Monitoring of Tropical Vegetation (MTV) Unit´s applications are ecosystem distribution and productivity, continental land cover/land use assessment, tropical forest monitoring and biomass burning. The tropical belt is the geographical focus of study, as this region contains the most actively changing of all the Earth's ecosystems.

In 1996 the TREES and FIRE projects moved towards operational systems providing guaranteed information on vegetation state and condition on a global scale. 1996 also demonstrated that microwave data (from ERS-1/2 and JERS-1) can significantly contribute to global monitoring of ecosystems. The Unit's work also demonstrated that several instruments can be meaningfully integrated such as to enhance their contribution to global and continental monitoring.

The Unit conducted a growing share of its research in close collaboration with international programmes. For example, the TREES project presented its data sets and results for exchange and validation by users ranging from global change researchers to local forestry service staff. Participation in the VEGETATION preparatory programme was established, and dedicated research conducted. Contributions to the preparation of other European and non-European instruments was also provided. Coping with large earth observation and ancillary data sets, and making such data available for analysis became a major activity in its own right. Efforts in the Unit focused on a Tropical Forest Information System and a Vegetation Fire Information System. User's requirements for access to global satellite products were also reflected in the design, in collaboration with industry, of automatic catalogue interrogation systems and interactive search procedures.

Advanced Techniques

The Advanced Techniques (AT) Unit concentrates on long-term research needed to support the development of remote sensing applications. The Unit is also responsible for the European microwave signature laboratory (EMSL) and an equivalent facility operating at optical wavelengths - the European Gonimeter (EGO).

Using the EMSL a three dimensional map of the radar reflectivity of a spruce tree was created; the first ever three dimensional SAR image of a natural target. The structural components of trees were also identified by making use of the polarisation characteristics of the radar reflectivity. Investigation of interferometry for industrial applications demonstrated that this technique can detect structural changes with a precision of 0.1 mm.

Environmental changes in northern European countries were studied by investigating the bi-directional and spectral characteristics of lichen and moss in the EGO. EGO was also used for the verification of computer simulated BRDF models for vegetative surfaces. Applied research using this facility focused on an investigation of paper quality. Competitively obtained work included contracts with DGXIII for the dissemination of EMSL radar signature reference data and an experimental investigation of the detection of road conditions by radar systems and the radar cross section measurements of different car types with Daimler-Benz, Ulm.

In addition to the large scale facilities, the Unit maintained its programme of fundamental research. The mapping of tree heights of a large area based on ERS SAR interferometric images, and realisation of an adaptive SAR processing algorithm to detect targets of known signatures covered by vegetation or embedded in soils are examples.

Significant progress was also made in the design of a mutli-sensor system for the detection and identification of anti-personnel mines.

Centre for Earth Observation

The Centre for Earth Observation (CEO) programme of the European Commission is focused on assisting users to benefit from earth observation information. Users can be scientists, government agencies or commercial organisations, that have professional tasks to undertake that may derive value from EO data and information. Following the unanimous approval of the participating countries via the Pathfinder Phase Steering Committee, and the formal approval of the JRC's Board of Governors, the CEO Programme in 1996 moved into the Design and Implementation Phase. This phase will take the Programme to the conclusion of the 4th Framework Programme at the end of 1998.

Four interrelated components have been identified as the basis for actions to meet the objectives of the Design and Implementation phase, namely Application Support, Enabling Services, User Support and Monitoring & Co-ordination. Many initiatives within these components were launched in 1996 and are expected to produce results towards the middle of 1997.

Throughout the year the Design and Implementation Phase was managed and co-ordinated by the project team based in the SAI's CEO Unit. The CEO project team has direct links with the thematic work of the other SAI Units, maintains close links with DGXII-D4 (Space Unit) which provides strategic and policy input to the CEO, and works with staff from other JRC Institutes - the Institute for Systems Informatics and Safety (ISIS) and the Environment Institute (EI).

In addition to the CEO project team, the CEO Unit also contributed to the SAI research programme through studies on the synergy of satellite communications with Earth Observation, and an analysis of the role of SAI in atmospheric chemistry studies.

The 1996 SAI Report

The following chapters describe the work of the SAI Units. Each chapter follows the same format, with an introductory section defining the overall objectives of the Unit.

The Institute's activities have had, and will continue to have a strong institutional character. The roles the SAI plays recognise the importance of the global perspective, neutrality and the subsidiarity principle. The work described in this annual report builds on previous research. However, where activities have reached sufficient maturity these will continue to devolve to external entities in the Member States and will no longer be addressed by the SAI. The mature parts of the MARS project are classical examples. The growing strategic work of the SAI, particularly with regard to the Centre for Earth Observation, and the expanded mandate for work with Space based navigation and telecommunications systems have had a profound impact on our work throughout the year and will continue to do so for the future.

Agricultural Information Systems

The Agricultural Information Systems unit (AIS) specialises in the application of remote sensing techniques for the monitoring of agricultural land. In 1996, the unit enlarged its expertise in environmental related applications especially concerning major hazards. Its main customer is DG VI (Agriculture), but in 1995 and 1996 its geographical field of application has been extended outside the 15 European Union countries. Its expertise allows the unit to manage large applications projects such as the MARS (Monitoring Agriculture with Remote Sensing) programme in support to DGVI or the MERA (MARS and Environmental Related Applications) project in Central Europe in support to DGI (External Relations). In 1996 two activities gained a wider recognition: support to the European Environmental Agency in the field of land cover changes, and the European Soil Bureau.

The expertise of the unit is based on two specific features: The use of remote sensing and spatial information techniques (GIS) for agricultural and environmental related applications: The ability to answer specific user requirements at a European level, by bringing together its own specific expertise as well as external ones through large application programmes.

The main activities of the unit relate to the specific demands of DGVI. The newly developed environmental activities of the unit such as risks and land cover are covered at the present time by the institute's research budget. Throughout the year too the unit enjoyed great success in obtaining resources under the competitive scheme requested by the Member States.

The unit has, over the years, built a huge data base of high and low resolution images, meteorological data, soil data and vegetation data, as well as specific computer programmes, such as the ORCA and GRIPS systems used operationally for crop acreage, the SPACE system to derive relevant information from NOAA-AVHRR data, CGMS (crop growth modelling system) and CACHOO system for the verification of farmers declarations, Copilot for the creation and updating of Corine land cover data base.

As in previous years the MARS programme (Monitoring Agriculture with Remote Sensing) remained the AIS Unit's primary focus. The objectives of the MARS Project are threefold:

- Improve agricultural statistics through the use of remote sensing techniques (MARS-STAT).
- Use remote sensing and related techniques to assist the implementation of the Common Agricultural Policy (MARS-CAP).
- Support the transfer of methods to other geographical regions outside the European Union (EU) and the adaptation of those methods to new themes (MARS Geographic Extensions).

1996 however saw diversification of the AIS Unit activities. The European Topic Center Land Cover is developing the information needed by the European Environment Agency (EEA) in the field of land cover. A Swedish organisation, MDC is in charge of the management together with a Portuguese organisation, CNIG and the unit. Within the consortium, we are in charge of coordinating the research and development part of the activities, which at the present time are mainly dedicated to updating the CORINE land cover data base, development of generalisation procedures and establishment of environmental indicators based on land cover data.

The European Soil Bureau is harmonising the data base and general mapping activities in soil relevant to Europe. It acts as an interface between the Commission needs and the national soil surveys activities.

Lacoast is a specific project which aims at defining and mapping the changes in the land part of the coastal zones.

Being based on the CORINE land cover methodology it covers only the countries which have such a database.

The ISIS project is developing new and more flexible data selection and data accounting schemes aimed at making the use of EO data more cost-effective for a wider user community. One of the salient features of this project is the use of High Processing Computing and Networking to facilitate access to, and dissemination of, Earth Observation data products from a number of server sites.

Most of the activities either institutional or competitive are multi-annual. The 1997 activities will be mainly to pursue and consolidate 1996 activities. However, some changes are foreseen in the agricultural policy of the European Union which will require adaptation of our methods and more specifically a re-engineering of some aspects of the MARS project. The geographic extension of the activities will be pursued and environmental aspects should be strengthened.

2.1

MARS-STAT Activity A: regional inventories

Summary of Objectives

- To develop and improve methods based on area frame sampling techniques and high resolution satellite image interpretation for agricultural or other land-use inventories at the level of the region.
- To develop software to carry out these procedures.
- To support regions in the Member States with the implementation of an operational system for land-use inventories.
- To support the implementation of regional inventories in the Central European countries which are the subject of the MERA PHARE project (Poland, Hungary, Czech Republic, Slovakia, Rumania, Bulgaria, Slovenia, Albania, Estonia, Lithuania and Latvia).
- Training and support activities.

1996 PROGRAMME OF WORK

1996 Milestones

June: Ground surveys in the main agricultural regions in Greece, Spain (national funding) and in parts of Portugal, Romania, Slovakia, Hungary, Bulgaria and Poland

October: Completion of the RIESLYNG software (Regional Inventories: Estimation of Surfaces and Land Yield from National Ground surveys) with new options related to segments that straddle strata borders

Introduction

Since 1993 there has been a gradual geographic shift of the MARS project's support activities towards the Central European countries and certain regions in southern Europe. In 1996 the MARS Project continued to provide technical support to the regions in the EC and to intensify its collaborations and training activities with the PHARE countries in the frame of the MERA Project (MARS and Environmental Related Applications). Technical advice has also been provided to other countries that have started to test the MARS Regional Inventories Methodology, in particular Turkey and Iran.

Methodology

The method is based on close links between satellite data and observations on the ground; the most cost-effective of these has been kept as operational. This relates to stratification by visual photo-interpretation of high resolution images. Medium resolution images, such as RESURS-01 (160m per pixel) can be used for stratification if landscape elements are large enough to be clearly identified at this resolution.

Studies conducted with data from the Spanish Ministry of Agriculture indicate that better stratification efficiency can be achieved with a two-phase sampling scheme, i.e., a systematic pre-sample and a subsample with a probability proportional to some agricultural intensity index obtained by photo-interpretation of the pre-sample. This leads to a different approach with the use of remote sensing for crop area estimation.

The standard method, based on a sample of square segments, is cheaper and faster to implement than alternative approaches, such as the segments with physical boundaries used by the US Department of Agriculture. We can distinguish three main components:

Ground survey:

Objective observations in the field with a sample of territory pieces often known as segments. This involves stratification using satellite images with existing topographical documents and maps in support; selection of a sample of square segments of a size that varies from region to region (16 ha to 200 ha); survey on the ground on the basis of aerial photographs, field drawings or only observing land cover on a sample of points. Remote sensing can give useful information to identify certain types of errors, such as location errors or missed identification of a field that has been recently split.

Farm survey:

A sample of farms are selected for interview through point sampling in the segments of the ground survey. This facilitates the calculation of the average number of sampled farms per segment.

Regression Estimator with Remote Sensing:

Automatic classification of the satellite data in order to improve the estimates generated by the ground surveys. This is achieved through the acquisition of regional coverages by SPOT or Landsat-TM images and the subsequent automatic classification and analysis of the satellite data using the regression method.

The regression estimator has proved to be feasible, but too expensive at the current prices for the efficiency obtained. Further improvement is needed in automating the procedure to make it cost-effective. It is only used for relatively small areas to test the efficiency in different landscapes. In 1996, it was used for one county in Hungary.

Perspectives for 1997

The activity on the Regional Inventories will be continued at JRC on a reduced scale when compared to the previous years. The MARS project will continue to supply technical support to the regions in the Member States, the PHARE countries, and other countries outside Europe partly through the development or enhancement of ad-hoc software systems, and partly through methodological studies to improve the sample design based upon specific requirements of the regions.

There is an increasing interest on applying the experience and methods developed through MARS Activity A for environmental studies, in particular to assess the quality of classification in the FIRS (Forest Information from Remote Sensing) Project and to calibrate the derived forest area estimates. A quality assessment of CORINE Land Cover has been also scheduled through cross referencing with ground data from Activity A.

2.2

MARS-STAT ACTIVITY B: european rapid estimates of areas under agricultural cultivation

Summary of Objectives

To provide decision makers in DG VI and EUROSTAT with early information at the Community level on annual changes in areas under agricultural cultivation.

1996 PROGRAMME OF WORK

1996 Milestones

March: Acceptance of the Preparatory Phase report

March/November: Monthly publication of the results in the MARS Bulletin August: Interim 1996 report for the Operational Phase accepted.

December: Final 1996 report accepted

Introduction

To obtain agricultural production estimates for a given crop, quantitative information on both crop yield and crop area is required.

In a first phase between 1988 and 1992, the MARS Project proved the feasibility of obtaining crop area estimatesp from optical satellite remote sensing data. Between 1992 and 1994, it demonstrated that these estimates can be attained operationally. In 1995, Activity B was considered fully operational and the transfer of responsibility from the JRC to DG VI for its execution was formalised together with the approval of the second phase of the MARS Project at the end of 1994 (Council Decision L299 of 22.11.1994). As part of its support to the Commission activities, the AIS Unit continued to provide technical and scientific support to DG VI/A/2 and to supervise the contractor, SOTEMA (France), responsible for the operation of Activity B.

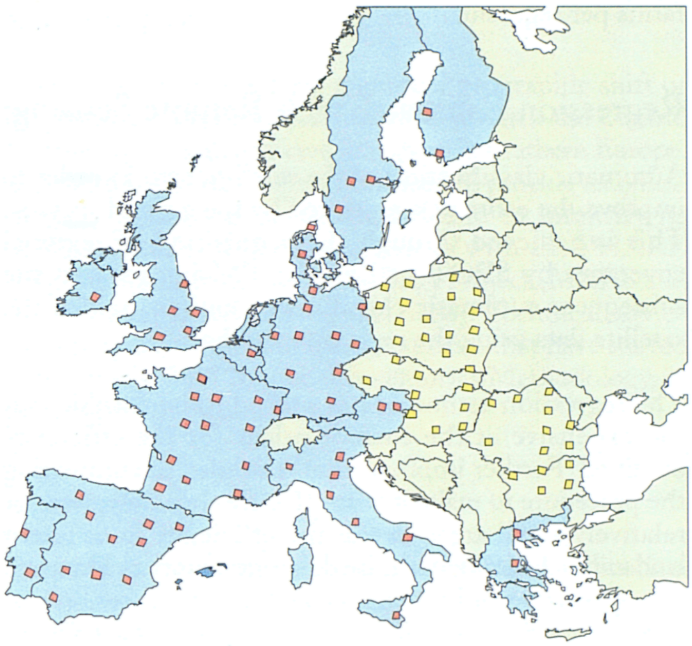


Figure 2.1 : Location of the 60 sites (red) to sample the E.U15 agricultural land cover and 40 sites in Central Europe (see also the section on MARS-Extensions.

Methodology and Results

The general methodology of Activity B takes the following steps :

- the acquisition of optical/infra-red satellite imagery for a sample of 40 by 40 km sites distributed over the European Union;
- the rapid transfer of those images from the receiving station and processing facilities to the Activity B operational service;
- the radiometric and geometric correction of the images; the photo-interpretation of fixed small image segments localised in a site followed by the unsupervised classification and analysis of the corrected images to derive the areas occupied by agricultural crops or groups of crops at each site;
- the statistical separation of the crops of interest at site level, followed by an aggregation of the results obtained over the different sites to the level of the European Union.

Since 1993, 53 sites of 40 km x 40 km each have been used to sample the European agricultural land cover. With the expansion of the European Union to 15 Member States, additional sites had to be chosen in the 3 new countries of Finland, Sweden and Austria. In total, 7 sites were defined early in 1995 and were included in Activity B for the 1996 campaign (Figure 2.1)

Window	Success Rate (%)		
	1994	1995	1996
1	77	85	100
2	94	98	96
3	98	95	87
4	86	92	92
Total	80	92	93

Table 2.1 : Comparison of the image acquisition in 1994, 1995 and 1996.

Image acquisitions

In 1996, images were acquired by either the Thematic Mapper onboard of Landsat 5 or the SPOT satellites. During 1996 171 (93%) out of the total of 183 planned images were aquired. Of those images 87% were acquired by SPOT and 6% by the Landsat 5 Thematic Mapper.

A maximum of 4 images per site are programmed for acquisition per year. This schedule is determined by four *"windows of opportunity"*, based on local crop calendars, to maximise the chance of discriminating between crops at the site. During the acquisition campaign, the image companies inform the Activity B service when they acquire a cloud free image of a site during an open *"window"*. Acceptance of this image by the Activity B service then closes the window for that site. Following acceptance, the image is rapidly shipped to the Activity B service, where it is calibrated and undergoes atmospheric and geometric corrections. The corrected image is then interpreted, classified and analysed to derive the agricultural crop area of the site. Image acquisition in 1996 was significantly improved compared to 1994 and slightly more successful than 1995, as indicated in Table 2.1.

Notice in Table 2.1 the significantly lower success rate for the 3rd acquisition window. Prevailing cloudy weather over most parts of Europe during June and the beginning of July seriously hampered image acquisition.

The improvement against 1994 can be explained by the combined effect of more favourable weather conditions in spring and autumn of 1996 and more efficient satellite acquisition by the image supplier. Delay in transfer of the images from the image providers to the Activity B service was also shortened. An average value of 3.1 days for 1996, against 5 days in 1995. This gain in time is important for the operational needs of the MARS Project, where images have to pass from acquisition to final information extraction in less than 10 days.

Geometric and radiometric corrections

Since 1993, these corrections are bundled in the operational software "Geometric & Radiometric Image Processing System" (GRIPS). Developed by GeoDesign and CISI (France), it performs the radiometric correction and geocoding of SPOT 1, 2 or 3 scenes at the 1A or 1B level in SPOT Image format as well as Landsat Thematic Mapper scenes, quarter-scenes or mini-scenes at 0 level (Raw Data) in the ESA/Earthnet format. The output data are geo-coded image products, whole or partial SPOT scenes at the 2A, 2B or 3 level in the SPOT image format or Landsat Thematic Mapper scenes or portions of scenes at the 5 to 10 level in the ESA/Earthnet format.

The image throughput of GRIPS is an important factor in achieving the performance criteria required in the operational context of Activity B. In 1995, problems were experienced in the third window of acquisition due to changes in the format of the SPOT images. Similar problems at the beginning of the season already jeopardised the processing of the Landsat TM data. Those problems did not occur in the 1996 campaign where the image providers carefully respected the operational requirements of Activity B.

Image interpretation and analysis

The tight schedule and the number of images to be processed impose an industrial approach to the image analysis. This involves a dedicated system comprising of computer-aided image interpretation without access to up-to-date ground data, a knowledge-oriented data base, automatic single-date classification, multi-temporal cross-classification as well as the validation of the interpretation once a year, using ground data collected specifically for this purpose. With the present software system, which forms the backbone of the information system, it takes an image interpreter about 2 days to analyse a single image. The peak sustainable throughput of the current system is just over 2 images per interpreter per working week. Combined with the other constraints of data volume and flow, this results in a system configuration where, for the actual number of active sites, 6 interpreters can work simultaneously and independently.

In 1994 the JRC initiated the development of a new interpretation and analysis system: "Orbital Remote Sensing for Crop Acreage" (ORCA). The ORCA system fully integrates production, quality control, database management, knowledge based interpretation and image processing techniques in a modular fashion. ORCA combines the experiences gained in the past and runs on a state-of-the-art client-server configuration of UNIX work stations. In 1996, the interpreters achieved an average throughput of 2.2 days per image, which was a significant improvement against the 3.1 days in 1995. This gain was partially lost due to a longer waiting period from an average 0.9 days in 1995 to 3.3 days in 1996 due to technical problems with the ORCA system during the beginning of the campaign. Nevertheless, the images still passed from acquisition to final information extraction in less than the nominal 10 days required.

Information Collation and Analysis

Essentially, the objective of this task is to establish, on a fortnightly basis, a value expressing the area change of 17 crops of interest for the EU. The experimental estimations at the level of the individual Member States published in 1995 were abandoned in 1996 due to the inadequate spatial sampling scheme at the national level. The estimation errors due to this under sampling were not acceptable. The conjuncture task can therefore be considered as the pivot of Activity B, where "raw data" is converted into statistical information. The crops of interest are the following:

- cereals, further divided in 5 crops, i.e. soft wheat, durum wheat, barley, grain maize and other cereals;
- the group of dried pulses with field peas and other dried pulses;
- the oil seeds group with rape seed, sunflower and other oil seeds;
- a mixed group of 7 crops, i.e. rice, potatoes, sugar beet, green maize, temporary grasses, perennial green fodder and fallow land.

The Information Collation and Analysis task is meant to overcome the three main obstacles in using images from sample sites for the estimation of areas under cultivation at European scale:

- The image radiometry observed at any given date may not always allow the separation of the crops of interest.
- At any given date, access may be denied to images of one or more sites at which a particular crop is present due to cloud cover or other image acquisition constraints.
- The contribution to a European estimate of a particular crop at a specific site depends on the acreage of the same crop at other sites.

Central to the Information Collation and Analysis task is the manner in which image classification results, ground survey data and ancillary data are combined and extrapolated from site level to the European scale. The Information Collation and Analysis task consists of 5 sequential phases:

1. documentation of the site;
2. transfer and preparation of the site classification results for collation and analysis;
3. separation of the crops, which are radiometrically similar or identical, for any given site for which images are available;
4. estimation of crop area for sites where no images are available, the so called "missing" sites;
5. extrapolation of the annual evolution per crop/site/group to the European level.

The precision and timeliness of the statistics produced by the collation and analysis task force are considered the touchstones of Activity B as a whole. Statistics given by other official or commercial sources are used as benchmarks against which the Activity B statistics are regularly compared. The principal reference is nevertheless provided by the EUROSTAT statistics, which are usually first published in autumn and continue to be revised until spring of the following year.

For the 1996 agricultural campaign, the winter and spring crop groups (mainly soft winter wheat, barley and oil seed rape) showed stable estimates as early as June. Moreover, the estimates converged rapidly with other, mostly commercial sources of information. For the group of summer crops, comprising sunflower, peas, potato, maize and sugar beet, firm results appeared from July onwards with again a high degree of convergence with other, albeit less timely, sources of information.

As was the case in previous years of operation, Activity B provided precise and early estimates of areas under different crops in Europe. The timeliness, objectivity and accuracy of the 1996 results contributed significantly to the satisfaction of the end user.

Perspectives for 1997

As in 1996, Activity B will continue under the overall management of DG VI - Agriculture (DG6/A/2) and with the scientific and technical collaboration of the JRC.

In support of the operational Activity B, the AIS unit will continue its research on quantitative yield estimation, integration of new sensors, innovative statistical sampling methods and improved image classification algorithms during 1997.

2.3

MARS-STAT ACTIVITY C: the advanced agricultural information system

Summary of Objectives

- Aid the assessment of crop state and yield estimates at EU, the Member State and regional levels.
- Assess the synergistic use of satellite data and agro-meteorological models for quantitative yield estimation and alarm identification.
- Integrate information on agricultural crop development, derived from agro-meteorological models and low resolution satellite data, with crop area estimates, extracted from a sample of high resolution satellite data, in monthly reports on the agricultural production in the European Union and the Member States.

1996 PROGRAMME OF WORK

1996 Milestones

March: The MARS software packages upgraded to include new Member States Sweden, Finland and Austria.

March/November: Publication of 8 monthly MARS Bulletins

June: The June Bulletin includes also, for the first time, an exploitation of the 1996 crop acreage ground surveys carried out between April and June

Installation of the NOAA-AVHRR receiving station at JRC

July: A prototype version of "LINGRA", the software module for the monitoring of the state of natural grassland

December: Installation of a prototype version running on PC of the NOAA-AVHRR processing software SPACE-II, version 2.0

Introduction

1996 was characterised by the parallel development of operational and research activities. The operational activities produced on a timely basis the monthly status reports on agricultural production. The research and development activities resulted in further improvements of the processing systems, such as the Crop Growth Monitoring System and SPACE 2.0, and development of algorithms and methods to increase the yield estimation accuracy.

Component 1: Vegetation Conditions and Yield Indicators

The principal objective of this component is to timely supply up-to-date information on the state of the vegetation over the whole of Europe. This entails monitoring the development of the vegetation during the course of an agricultural season using essentially low resolution satellite data (1 km^2 at nadir) captured by the Advanced Very High Resolution Radiometer (AVHRR) on board of the National Oceanographic and Atmospheric Administration (NOAA) meteorological satellites.

Operations

In the operational context of the MARS Project, multi-temporal vegetation and surface temperature indices derived from the AVHRR data are used in a qualitative, contextual way to compare from year to year to the next or over a given period, the vegetation development for any given region in the European Union. This allows to identify "alarm" situations, such as a prolonged drought, to compare these findings with the agro-meteorological observations and to assess the impact of these events on the agricultural yields in the data fusion context of the Integrated System. The analysts who produce the MARS Bulletin, are therefore the principal clients.

For the pre-processing of the AVHRR NOAA level 1B scenes into calibrated, geometrically and atmospherically corrected European mosaics, the MARS Project employs SPACE (Software for Pre-Processing AVHRR data for the Communities of Europe). The daily AVHRR mosaics produced by SPACE, i.e. the level 3 products, are the input for the production of images, maps or temporal profiles of geophysical parameters such as vegetation and surface temperature indices.

Research activities

Despite the corrections inherent in the SPACE package, cloud influences and bi-directional effects still introduce perturbing effects. To correct these, a NDVI temporal profile smoothing method called INTUITIV was developed. Despite encouraging results obtained when using INTUITIV smoothed data, some problems appeared when analyzing them in detail. One example is shown in Figure 2.2. It can be seen that, even if the obtained NDVI temporal profile seems to be correct, the corresponding reflectances profiles are unrealistic.

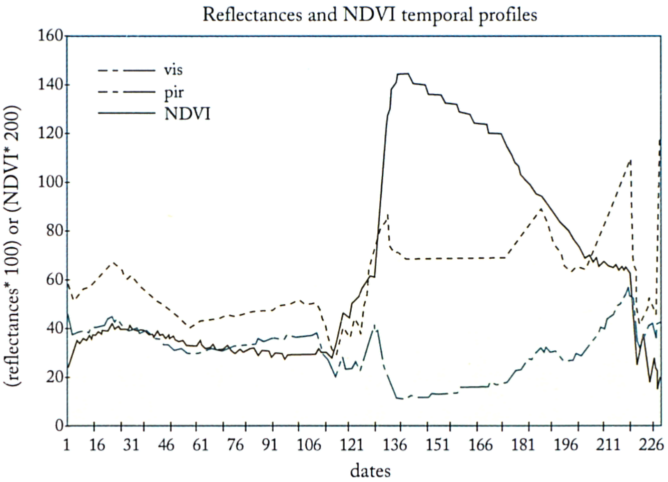


Figure 2.2 : example of unrealistic reflectance temporal profiles with the corresponding temporal NDVI profile.

Thus in 1996 a new smoothing algorithm has been developed. Instead of using the NDVI temporal profile this processes values from the visible and near infrared channels. The different steps of the algorithm are shown in Figure 2.3. The algorithm is called ARC (AVHRR Reflectances Correction). Data processing is achieved on a pixel per pixel basis in order to obtained smoothed temporal profiles of reflectances.

The result is temporal profiles with fewer anomalies which can be readily incorporated into subsequent components of the AIS.

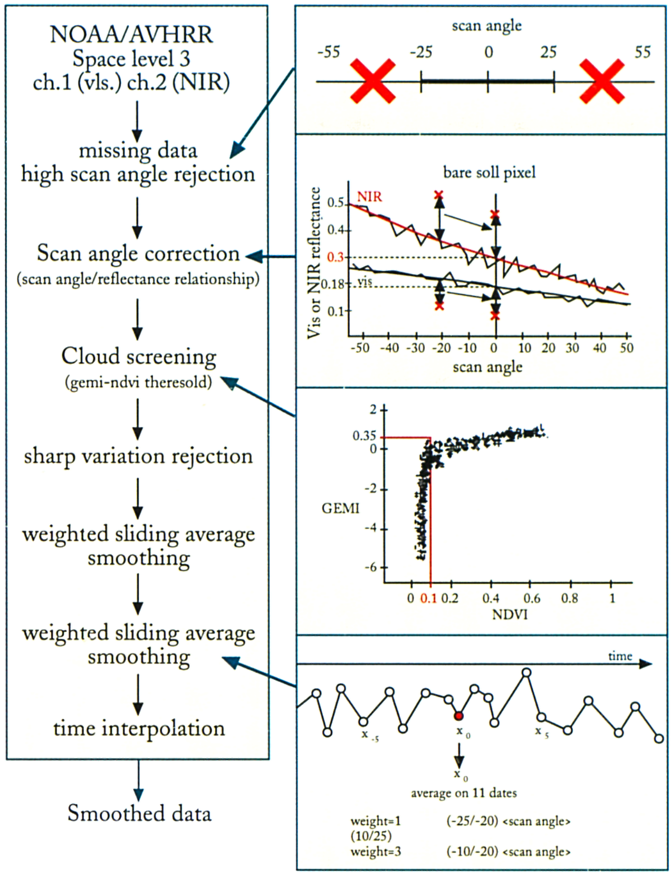


Figure 2.3 : Different steps of the AVHRR Reflectances Correction (ARC) methodology.

Component 2: Yield Prediction Models

The objective of component 2 is the development, testing and implementation of a system for the timely area-wise crop state monitoring and quantitative yield forecasting at EU level of the following major crops: cereals, grain maize, rice, pulses, sunflower, Soya bean, potato, sugar beet, rape seed, grape-vine and olive.

This involves the development and improvement of a semi-deterministic agro-meteorological model to predict annual crop yields, and the development of a model to forecast vine (and olive) yields based on pollen count methods.

Agro-meteorological Crop Growth Simulation of Annual Crops

The Crop Growth Monitoring System (CGMS) is the MARS agro-meteorological modeling system based on the WOFOST model which uses data on soil and meteorological conditions to simulate crop growth. The system is used on a regular basis to produce 10-day outputs and monthly summaries of : (1) meteo condition indicators and (2) crop state indicators, including development stage, leaf area index, soil moisture index, total biomass and storage organ biomass for either water limited or irrigated conditions. The outputs are prepared for each of these ten crops in cartographic format on a 50 km x 50 km grid square basis. CGMS can be used to illustrate the absolute values for the present season or to indicate the deviation between the present season and the long-term average. It can also combine these modelled crop state indicators with actual yield and production statistics from previous years to provide a quantitative yield estimate for the current season on a national or European basis.

The outputs of the system are mapped outputs of indicators on the quality of the agricultural season, alarm warning, tables with calculated yield forecasts. Intensive research has been carried out this year to improve the reliability and usefulness of the outputs. For example, concerning wheat production, research has demonstrated that prices of the previous year can account for the annual production variation of various countries. However, prediction results do not improve when prices are introduced in a prediction model.

Other research focused on statistical analysis. This indicates that CGMS results do not account significantly for the variation of the national yield for various crops. However, CGMS results do account for the variation of the national production.

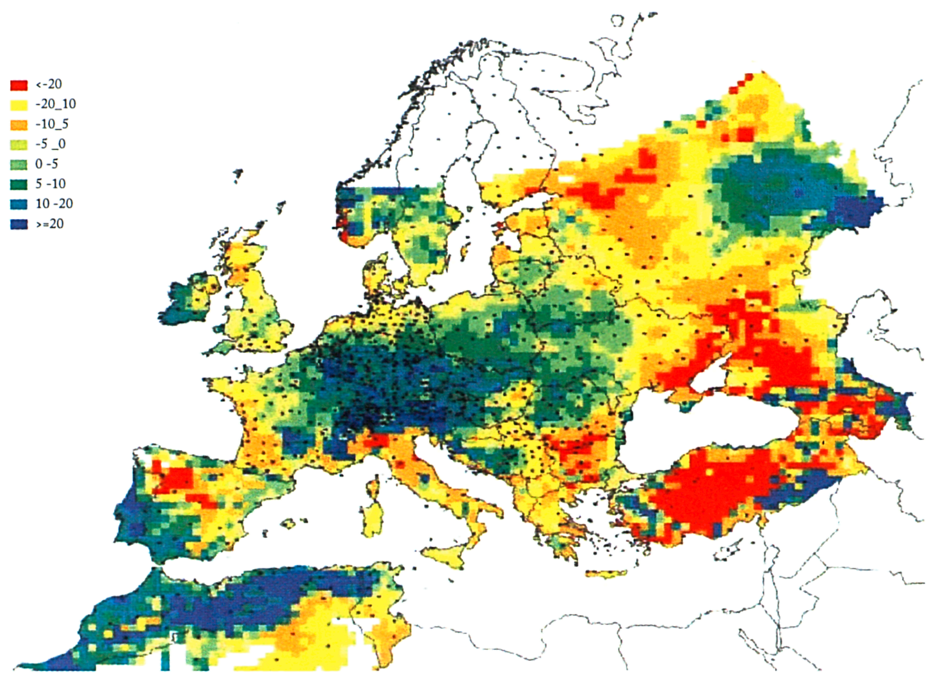


Figure 2.4 : The potential production of winter wheat in 1996, shown by its simulated grain production.

Because the acquisition of reliable and independent yield forecasts by traditional ground surveys are too difficult to be managed at the scale of large European regions, MARS relates agrometeorological model parameters to remotely-sensed data. This results in improved dry matter, and then, yield estimations.

The EU Support Group on Agro-meteorology "SuGrAm" closely monitors these activities and, through panel discussions around similar research going on in other research institutes, contributes to the effective introduction of these approaches in the MARS Advanced Agricultural Information System and to the development of a long-term strategy on the combined use of space and ground based information for agricultural information collection purposes.

The Pollen Count Model

In 1996, the European network, which covers 45 pollen capture posts was further refined and operated by the French CEMAGREF (Bordeau section), in collaboration with the Aeropalynologic Laboratory of the University of Montpellier. In this network, more then 15 posts are co-financed by national or regional institutions in France, Portugal, Italy and Spain. CEMAGREF and the Laboratory for Aeropalynology of Montpellier are also responsible for the analysis of the results.

A new approach for the analysis of the results was tested. This consists of relating differences from year to year in the grapevine production, with inter-annual differences in numbers of released pollens. This makes the method less dependent upon changes in the grapevine acreage and also requires less years before the results can be exploited operationally.

A detailed manual was further published. This describes the method, site selection procedures, the laboratory analyses and the interpretation approach. The manual will enable European, national or regional authorities to start operating the network on their own behalf. The method is now considered to be pre-operational and ready for a gradual transfer to Member States.

Component 3: the Integrated System

The objective of this component is to integrate the various actions and also incorporate conventional surveys to create a complete information system including the new methods described above.

Results of the Integrated System: the MARS Bulletin

The AIS produces monthly bulletins on crop behaviour and yield forecast. In 1996, the MARS Bulletin was issued monthly from March to November. The graphic layout was changed, providing more accessible and comprehensive information to the different levels of potential readers. Each issue of the Bulletin refers to the most recent information acquired on agriculture, taking into account the time needed to process satellite images and meteorological data - a gap of 5 days. Distribution was extended from DG VI and EUROSTAT to also include the Member States.

The MARS Bulletin contains the results of the analysis on the agricultural campaign over the whole of Europe, using all information available within the MARS Project. In 1996, the analysis at national level was performed on soft wheat, durum wheat, barley, grain maize, sunflower,

Expected crop behaviour maps
Situation at end of September 1996

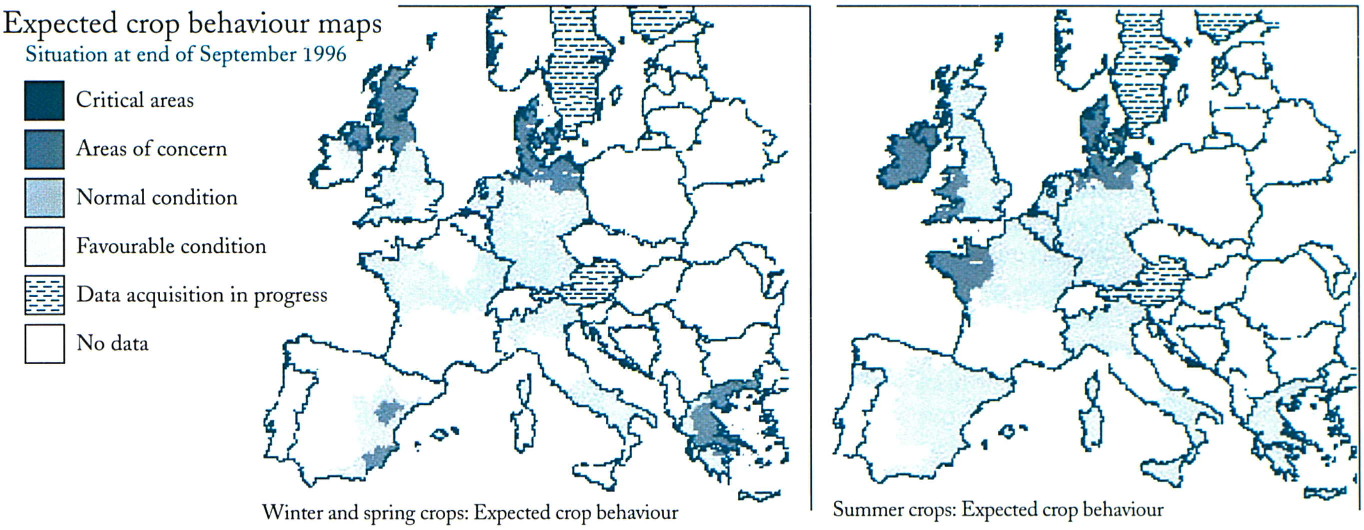


Figure 2.5 : Synthesis of crop behaviour at the end of the 1996 agricultural season.

potatoes, spring barley, rape seed and potato, and also saw a first year of analysis for the new Member States.

The main information given in the Bulletin regards estimated crop area changes (at European level) and yield forecasts (at national level). The acreage changes are entirely derived from high resolution satellite images acquired from a sample of 60 sites in Europe. Seven new sites on the new member states were fully integrated in the area change estimate activity. The yield forecasts are established in more steps, using:

- raw outputs of the CGMS, namely meteorological statistics and agro-meteorological simulations for each crop of interest;
- NOAA-AVHRR derived information on vegetation coverage;
- a deep trend analysis of the yield time series; ancillary information available from ground surveys.

The data are always studied taking into account their spatial position and time evolution. An interdisciplinary group analyses the results obtained from the different sources and puts forward scenarios on crop behaviour. The quantification in t/ha of yield is obtained by applying statistical models, where the predictors, trend included, are chosen according to their capacity in explaining the potential yield at that moment in the year.

The yield forecasts in the Bulletin are helpful because of their early availability and reliability, thus representing a clear improvement over available official national data for policy and decision makers. A synthesis of crop behaviour at the end of the 1996 agricultural season is provided in Figure 2.5.

Perspectives for 1997

In 1997, the following R&D activities related to the use of agrometeorological models and low resolution meteorological satellite data for crop yield forecasting will be undertaken:

the integrated use of NOAA-AVHRR data and agrometeorological models, development of a the crop knowledge base, global radiation analysis, improved calculation of AVHRR-derived indices and on technological trend, as

EU-15	Prod. 96-95 change (%)	Coeff. of variation	Prod. 95 (Mt)	Est. prod. 96 (Mt)	MARS fore-casts	EUROSTAT statistics (Mt)
Soft wheat	13.4	3.7	80.5	91.3	89.0	91.3
Durum wheat	8.8	7.4	7.1	7.7	8.9	8.7
Barley	23.5	7.6	43.7	54.0	50.6	52.9
Grain maize	5.3	4.6	29.8	31.4	31.8	34.0
Other cereals	11.5	8.5	16.6	18.5	19.5	20.9
Total cereals			177.7	202.9	199.8	207.7
Dried pulses	-1.4	13.5	4.8	4.7	4.9	-
Potatoes	9.2	15.3	44.9	49.0	46.3	-
Sugar beet	12.0	15.5	111.6	125.0	120.6	-
Sunflower	32.7	13.8	3.4	4.5	4.0	-
Rapeseed	-10.2	15.9	8.1	7.3	7.2	-

Legend: Mt=millions of tons;
MARS forecasts: MARS production estimates of October 1996;
EUROSTAT statistics: final EUROSTAT assessments of 15 January 1997, the most recent official statistics available.

Table 2.3 : Estimated changes in production for the main crops from the previous year, and estimated production for the current year, based on data collected through the yield survey at the point level; as compared with MARS forecasts of October 1996 and EUROSTAT statistics of 15 January 1997.

operational tools in the MARS Advanced Agricultural Information System.
Finalise and possibly implement the results of the feasibility study to integrate Meteosat data in the MARS Crop Growth Monitoring System.
The use of NOAA-AVHRR derived vegetation indices as statistical variables for yield prediction
The use of NOAA-AVHRR derived vegetation indices for crop state and drought monitoring at the European scale.
The use of the ERS-Scatterometer for early drought detection at the European scale.
The use of the crop development stage rather then the calendar date, as reference date for the calculation of the departures from the long term normal of crop state indicators.
Sensitivity analyses on the various modules, inputs and algorithms of the Crop Growth Simulation System.
Generalise the present Crop Growth Monitoring System, which covers only annual crops, so as to accommodate also the perennial crops grapevine and olive, and grassland.

Component 4: Area Frame Surveys

This component provides image interpreters carrying out the "European Rapid Estimates" Activity with the ground data to build a knowledge base for each site for the year (n-1) and validate the obtained results by satellite data in real time at the end of each year. It also obtains direct estimates of acreage and yields for the main agricultural crops at the European Union level, independently of remote-sensing techniques, and provides information at the site level which may be used by other prediction models.

Results

In 1996, the Area Frame Sampling Survey was characterised by three main aspects:

- In the three new Member States, the Survey was carried out for the second time;
- The Survey was already well known to the contractors who participated in the 1995 ground survey;
- Unexpected delays in the start of several contracts deferred the start date of the point crop survey by a few weeks in those countries.

The Area Frame Sampling Survey was carried out in the 60 sites of Activity B, "European Rapid Estimates", of the MARS Project.

Area Frame Sampling Survey encompasses a two-stage survey:

- a point crop survey, carried out in the fields generated by the sample points;
- a yield survey, carried out through a questionnaire used to interview farmers, covering not only the field generated by the sample point, but all crops on the farm. The interviewed farmers are those whose fields enclose the point(s) where an agricultural land cover is present.

The framework as well as the results of this Survey should be fully compatible with the "European Rapid Estimates" Activity. To undertake this activity at the European Union level, MARS had therefore to define a consistent survey method to implement a quality check; to develop a common software (MAGDA), tailored and delivered to each country, for storing and checking the data; to develop specific ground survey documents based on high-resolution satellite image data; and to prepare a common nomenclature system for crop-code assignment.

Table 2.3 shows the estimated changes in production for the main crops from the previous year, and the estimated production of the current year, based on data collected by the contractors through the yield survey at the point level. These estimates were derived by the MARS statisticians, taking into account the data delivered by the contractors up until that point. The table also relates these estimates to the MARS forecasts of October 1996 and the EUROSTAT statistics of 15 January 1997 (cf. Table 2.2).

Perspectives for 1997

In 1997, the Area Frame Sampling Survey is scheduled to be carried out in the 15 Member States of the European Union. Whereas the point crop survey will be carried out in and supplemented with regional expert reports from all 60 sites, the yield survey will be optionally performed in 12 selected sites only. The results of the acreage and yield estimates will be timely divulged in a bulletin. The acreage estimates will be checked against information submitted by the contractors during the panel meeting in late June.

The inter-annual changes in acreage of each land cover class in those sites will be analysed. A similar analysis over time will be performed for the yield components. An evaluation of each site "value" will be achieved, to permit a sound decision about the future strategy for that activity. The study of the crop calendar of each site will continue, based on the data of an additional year. The unique database containing all results of the Area Frame Sampling Survey since 1989 will be updated with fresh results from 1997.

2.4

MARS-STAT ACTIVITY D: foreign agricultural production forecasting

Summary of Objectives

Monitor and forecast the agricultural production of countries outside the EU (central and eastern Europe, Turkey and Maghreb).

1996 PROGRAMME OF WORK

1996 Milestones

January/April: Organization of the acquisition, collection and archive of the basic input parameters.

May/October: Set-up and improvement of the system for crop growth monitoring outside the EU based on the existing CGMS system.

Delivery to DG VI of a monthly bulletin for monitoring crop condition over the extended area

1996 Results

The system for the forecasting of foreign agricultural production was designed to cover central, eastern Europe, Turkey and the Maghreb region. It was created on the basis of the existing experience with crop yield forecasting for the EU Member States in which an agro-pedo-meteorological model is used. The administrative and 50 km grid coverages were installed. The necessary input data and parameters were partially collected and the corresponding archives organized. These contain the meteorological data, the soils database, the time series of agricultural production statistics and the 1996 NOAA-AVHRR coverage over the whole area. Crop knowledge databases are being progressively compiled.

A study was carried out to verify if the existing MARS approach for yield forecasting could be simplified and adapted to the specific conditions of this area. Since the recent and rapid socio-economic changes also affect the agricultural production system, the model to be applied cannot rely on a well established agricultural trend.

This year 5 periodic bulletins from May to October were produced, processing near real time weather data in order to be able to deliver an agrometeorological monitoring bulletin within 10 days after meteo data reception.

Perspectives for 1997

The dominant activities of 1997 will be the production of operational qualitative outputs related to early crop state monitoring, the validation of results and the progressive improvement of the forecasting system. The necessary research on key topics will be launched to refine the system. Such refinement might involve :
the integration of other crop parameters such as spring cereal and maize in the system
the integration and processing of the 30 years archive meteo data
the stratification of the area to focus the estimates on agricultural zones. CORINE Land-Cover database and the Russian Satellite RESURS will be used to provide the required input information.

2.5

MARS-STAT ACTIVITY E: new methods and sensors

Summary of Objectives

- Assess the potential of microwave remote sensing data to provide information regarding agricultural crops area, crop state or specific geophysical parameters which can be used either as input for modelling or as substitution of optical remote sensing data.
- Evaluate the potential of new data analysis techniques to achieve certain objectives of the MARS Project, especially those of Activity B.

1996 PROGRAMME OF WORK

1996 Milestones

January: Kick-off of a large scale pilot project (20 Activity B sites) on the use of ERS SAR data for rapid area estimation of agricultural crops

August: Publication of a call for proposals for a second pilot project on the use of ERS SAR data for rapid area estimation of agricultural crops covering all the 60 sites of the Activity B

Introduction

During 1996, Activity E mainly focused on pre-operational studies regarding the integration of ERS synthetic aperture radar (SAR) in the operational Rapid Estimates Activity, Activity B. The encouraging results regarding the very early estimation of crop areas obtained in the experiments of 1995 was further evaluated in a 1996 pilot project on the use of active microwave satellite remote sensing data for rapid area estimation of agricultural crops.
The pilot project was conducted on behalf of the Directorate-General VI Agriculture by a consortium of companies led by GAF (Germany) with as partners the NRSC (U.K), Synoptics (NL) and sub-contractors Scot Conseil (France) and RSAC (U.K).

The pilot project covered 20 Activity B sites for which the probability in obtaining early optical data is relatively low. Up to four ERS-1 scenes per site, nearly all located in north-western Europe, were acquired through winter and early spring of 1996 and analyzed by interpreters belonging to a consortium of companies. The interpreters were trained with the support of the JRC in applying the methodologies developed in the MARS Project. Despite the nearly operational character of the pilot project, an intensive ground survey campaign was conducted for 8 of the 20 sites. During this campaign, parameters such as soil roughness, tillage, row direction, soil moisture and crop types were collected on a number of occasions. These data were used both to validate the results of the unsupervised interpretation work and to supply input to more research oriented activities, involving the modeling of microwave signals from bare soils.

Results

Unfortunately image availability was restricted by a low acquisition rate at ground receiving stations. The project had to use images acquired at non-optimal times for crop type discrimination. However for 18 out of 20 sites 3 images were obtained.

Once all three images were processed analysis could begin. While in the majority of cases data could be provided within two weeks, in 8 cases the last images were delivered more than 3 weeks after ordering the data, with a maximum delay of 41 days. This postponement directly affected the

Synthetic Channel composite colour	RGB composite colour	Backscattering signature	Synthetic Channel	Most likely crop class
Yellow	White	high in all channels ⇒ ploughed fields throughout the period	high in channel 1 and 2 (mean and range), maximum in first image	summer crop
Yellow-white	Light blue	high in channel 2 and 3 (stubble to ploughed field)	high in channel 1, 2 and 3, maximum in second or third image	summer crop
Green	Green	high in channel 2 only ⇒ stubble to ploughed to seedbed	high in channel 2 only, high dynamic range due to roughness transitions ⇒ maximum in first image	failed winter cereal or spring crop (cereal)
Green	Yellow-green	high in channel 1 and 2 ⇒ ploughed to seedbed	idem	spring crop
Deep red	Pinkish, red	high in channel 1 only ⇒ ploughed to seedbed	high/ medium in channel 1, low dynamic range, maximum in first image	late winter cereal
Pink	Grey	medium backscattering level throughout series ⇒ seedbed	medium in channel 1, low dynamic range, maximum in third image	winter crop
Dark blue	Black	low backscattering level throughout series ⇒ grassland	low in channel 1, low dynamic range, maximum in third image, due to increased vegetation cover	grass land

Table 2.4 : Explanation of coloured clusters appearing in the synthetic channel composite and CGF combination. See Figure 2.6 (colour indications as they appear on a computer screen).

image interpretation activity. In addition, data were delivered in batches. Thus, the data could not be processed continuously, but in intermittent peak periods.

The interpretation was preceded by the generation of image masks. The masks were derived from the classifications of the optical data of the previous year. The multi-temporal data sets for a given site were subjected to a transformation into synthetic channels. These were generated to improve the detection of change in the data and to de-correlate the channels. For this purpose an algorithm was provided by the SAI. An example of the processed SAR (Calibrated Geo-referenced Filtered (PRI) image CGF) images and Synthetic Channel output is presented in Figure 2.6. table provides a key.

An unsupervised classification was then applied on the synthetic channels. With the aid of information from previous years, such as field survey data from the area frame sampling activity of the MARS Project and optical data, the classes were related by the interpreters to crops or groups of crops. The coding of the classes followed the coding used in Activity B to allow an integration of the interpretation results from SAR with optical data. As the interpretation results became available they were transmitted to the agricultural statistician. The data were used to generate estimates of European crop acreage for crops of interest.

The performance of the tasks was expressed as the average time taken to complete the stages of ordering, processing, transport and interpretation of the data. The average data ordering time was 13.2 days. On average the data was processed in 13.1 days. For the transport of the data by delivery 2.5 days were recorded. The interpretation took 13.3 days per site. The times stated are not typical times

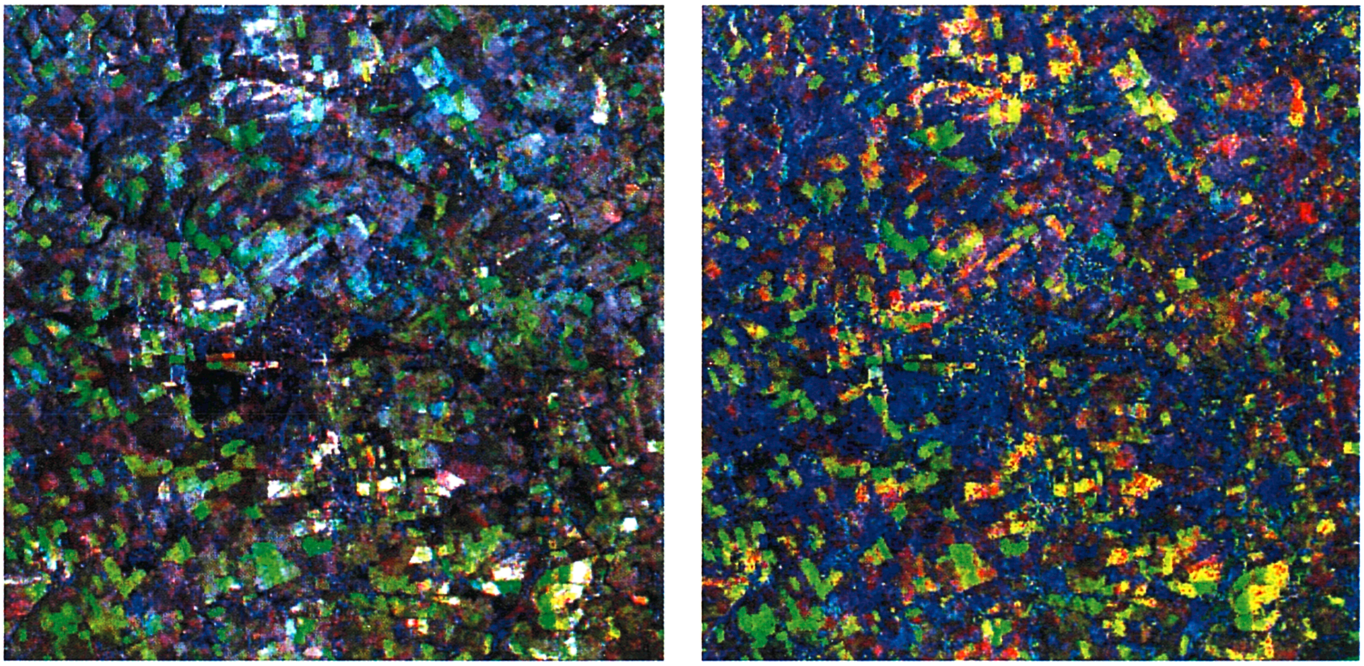


Figure 2.6 : SAR Composites.

CROPS	Mars Bulletin N°. 2/96			Combined Optical & SAR Data	Mars Bulletin N°. 8/96
	AREA			AREA	AREA
	1995	1996	Change	Change	Change
	1000 ha	1000 ha	%	%	%
Cereals	35559	36591	2.9	2.9	4.2
Soft wheat	13390	13730	2.5	4.0	5.3
Durum wheat	3080	3140	1.8	1.9	1.9
Barley	11050	11720	6.1	4.9	2.6
Grain maize	3750	3920	4.5	4.4	2.2
Other cereals	4280	4140	-3.4	-5.9	8.1
Other crops	1640	1620	-1.1	-1.4	6.8
Peas	1023	1004	-1.8	-1.9	-0.6
Oilseed Rape	2780	2840	2.1	1.5	-1.9
Fallow land	11610	9270	-20.1	-19.8	-19.5

Table 2.5 : Comparison Between Area Estimates of the MARS Bulletins and Combined Optical & SAR Data.

for the tasks involved. They include the delays in image delivery due to queries concerning the quality of the data, questions concerning the filtering of the data and interrogations by the agricultural statistician as to the results transmitted by the interpreters.

As part of the task to estimate crop acreage the influence of the data treatment as applied in the statistical program on the results of MARS Bulletin No. 2 were investigated. It was found that the definition of neighbouring sites (zones) was of significant importance for the estimates. Changes in the grouping of the sites, which are set as a priori knowledge by the agricultural statistician, lead to considerable changes in the estimates. Of further consequence on the results is the weighting introduced by the indirect transfer of site data to European estimates. The findings underline the importance of the statistical program and the algorithms used in producing European crop area estimates.

A combination of SAR with optical data was created to investigate the usefulness of the data in an operational environment. In 1996 the first estimates of a MARS Bulletin were published in Bulletin No. 2 (end of April). The bulletin contained estimates based on first optical images of 30 MARS sites. Of the 20 SAR project sites only 8 were covered by an optical image. The results form the 12 sites with SAR coverage were combined with the 30 results obtained from interpreting optical data. It was intended to investigate, if significant differences in European crop area estimates existed between the bulletin and the combined data. The differences observed were relatively minor and are expected to be within the range of the variation around the estimates.

The results from the bulletin and the combined estimates were further compared to the final estimates of the MARS Project as published in Bulletin No. 8 (October) see Table 2.5. For all cereal crops, except for the group "other cereals", the estimates obtained from the combined data were closer to the final estimates than the optical estimates. However, it should be stressed that differences between the estimates derived from the optical data and the combined data were not significant. The improvements observed may also be attributed to chance by the variation in the data.

Perspectives for 1997

1996 results justify a follow on project. The 1997 project will cover all the 60 Activity B sites with up to 6 ERS SAR data acquisitions distributed over a fall/winter and an early spring monitoring period.

Further research will be conducted using SAR data acquired by RADARSAT, which was launched at the end of 1995. The advanced technical capabilities of RADARSAT, especially regarding the imaging geometry and the broad range of products which can be generated, open promising perspectives for the further use of space borne SAR data to map and monitor crops.

2.6

MARS-CAP activities

Summary of Objectives

- Provide technical support to DG VI in the definition and follow-up of the implementation within the European Union of Agricultural Policy, for the specific points requiring data or tools to manage geographic information: Integrated Administration and Control System, Vineyard and Olive-Tree registers.

1996 PROGRAMME OF WORK

1996 Milestones

January: Study for the evaluation of the use of GIS for parcel identification system management

March: Launch of the Control with remote sensing contracts carried out by national contractors and followed-up by the JRC. Preparation of technical recommendation on tolerances and decision rules

May: Decision in principle by DGVI to integrate arable, vineyard and olive tree identification under GIS in certain Member States

August: Launch of the Quality Control on remote sensing contracts project, managed by JRC (performed by Hunting TS)

October: Completion of a study concerning the use of GPS for agricultural parcel measurement

October: GPS seminar for Member State administrations

November: End of the Control with remote sensing contracts and organisation of the final technical meeting. (Baveno conference)

December: Note from the Commission to the Council on the Control with remote sensing. In this frame, contribution of the JRC in the field of a cost/efficiency study

31 Dec 1996: Full implementation of IACS - Regulation deadline

Introduction

Since 1993, the Common Agricultural Policy has applied the principle of area-related subsidies - managed under the Integrated Administration and Control System (IACS) - to all EU-subsidised arable and forage land. The IACS presently concerns payments in the 15 Member States relating to:

- cereals, oil seeds and protein crops,
- set-aside fields, under its different forms,
- forage areas (fodder crops, permanent or temporary meadows, etc.), which provide the basis for the allocation and control of several animal premiums.

The IACS relies upon a yearly application by farm managers, containing detailed information on the parcels managed by a holding, called an "Area Aid Application" (AAA). The information provided under the AAA should give the location, area and use of all agricultural land on the holding, data which is inherently geographical and well adapted to remote sensing and GIS techniques for data collection, processing, and management.

Based on the variable national contexts to be found relating to land registration and mapping resources, different choices have been made by the Member States for the identification of agricultural land. Each either applies existing maps (e.g. land registers, large scale topographic maps) or creates new reference maps and numbering systems (dependant upon the use of aerial photographs and orthophotomaps or the adaptation of digital map databases, etc.). This leads to a complex range of technical alternatives and the requirement for direct technical support to DG VI in the evaluation of these systems. The MARS-CAP project is particularly involved in contributing to the technical management of these large area projects (60,000 km^2 and upwards) in Ireland, Portugal and Greece. However, the technical management ultimately remains in the hands of the national administrations concerned.

Additionally, the project provides technical "know-how" to DGVI in assessing and evaluating the "parcel identification systems" (PIS) in the Member States in general. These types of activities are grouped in Activity G of the MARS project: Implementation of the Integrated Administration and Control System (IACS) within the 15 Member States.

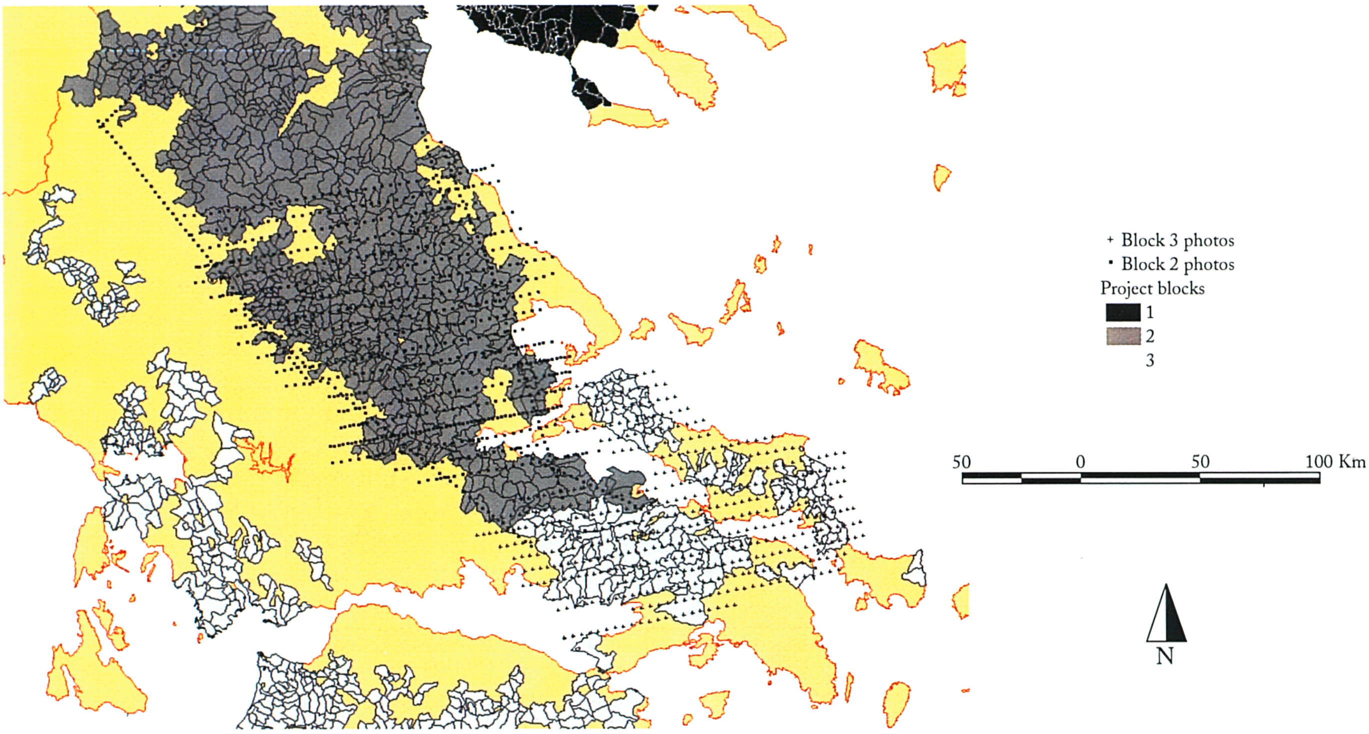


Figure 2.7 : Orthophoto coverage, positioned by airborne differential GPS, for Central Greece (photo positions courtesy of CGR SpA, Parma) showing the three main project block zones.

In parallel, farmers' applications for agricultural subsidy have to be checked; the relevant European regulations note a minimum obligation of 5% in-situ checks to be carried out by the national Administrations. Once again, the use of satellite and airborne imagery has proved to be an efficient tool when applying the application specific "Control with remote sensing" methods developed by the MARS project. These methods have been in place since 1992 and are under constant improvement and development.

The JRC also provides technical support to DG-VI and the national Administrations on the follow-up of the contractors charged with these operations within the Member States. Specifically: definition of technical recommendations, inspection of the contractors, evaluation of the results, and particularly since 1996, an operational Quality Control on the contractual work carried out in each Member State. These activities are grouped under Activity F of the MARS-CAP project: "Control with remote sensing".

The technical follow-up of the regulations on the Vineyard and the Olive-Tree sectors is also part of the activities of the MARS-CAP sector (Activity H), which involves the implementation and the management of "Vineyard and Olive-Tree Registers", i.e. computerised systems to localise and manage individual parcels.

The year was mainly dedicated to:

- the evaluation of the existing systems and the updating of their data (with field missions carried out with DG-VI in Italy, France, Germany, Spain and Portugal).
- a basic review of the new definition of the registers, which are now named GIS-VITI (vineyard GIS) and GIS-OLI (Olive tree GIS), enhancing the requirement for geographic information. New regulations are currently in preparation and are aimed at simplifying the systems (i.e. to focus the GIS-VITI functionality on the management of area-related subsidies or rights) and on the possible integration of these systems with the IACS.

The project has been active in five main areas during 1996:

- PIS creation projects in Ireland, Greece and Portugal have all seen fundamental developments. This year alone IACS-related orthophoto coverage created in the EU will be of the order of 210,000 km^2. The MARS-CAP project has been fully involved in providing help to DGVI and the national administrations concerned to keep these projects on target and of acceptable quality.
- A follow-up study to preliminary research the use of differential GPS equipment for the area measurement of farmers' parcels (including field trials in Finland, France and Portugal) has enabled clear statements on the suitability of the different systems available on the market and has made possible the assessment of the interest in using (with respect to accuracy or operational limitations) code processing systems in differential mode. A seminar (attended by over 70 participants) successfully brought together commercial organisations and those responsible in national administrations for a three day meeting at the JRC.
- With regard to the identification of vineyards and olive trees for subsidy management, decisions taken within DGVI have moved the concept of geographic data management into primary place. The concept being developed by DGVI, with support from the MARS-CAP project, will bring the three separate systems (IACS, Vineyard, Olive tree) into a compatible

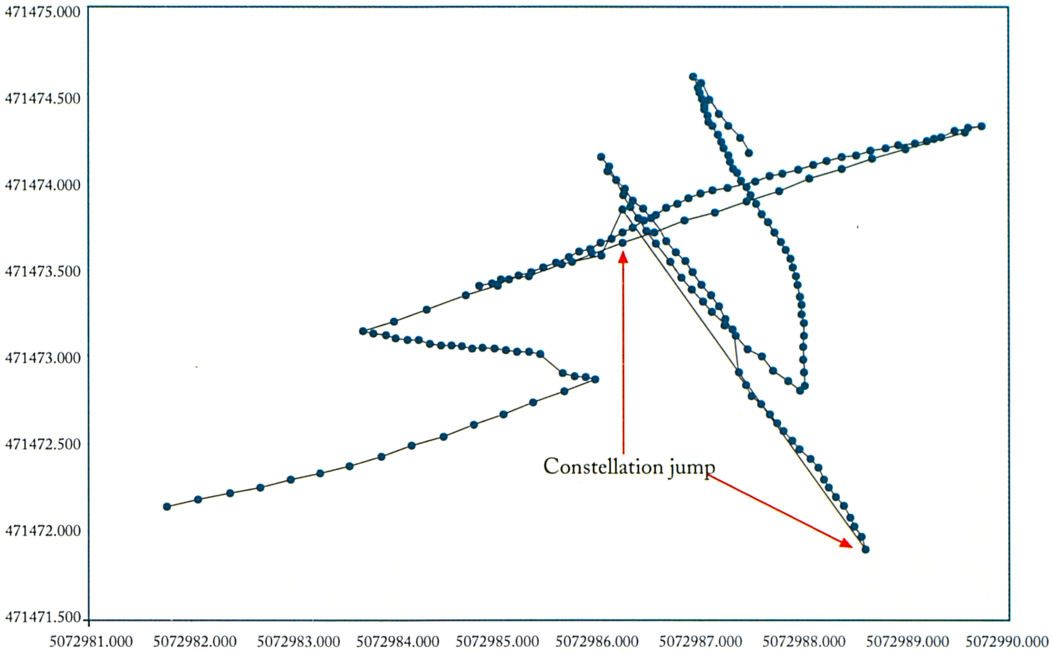


Figure: 2.8 : The effect of satellite constellation change upon differentially corrected code-phase GPS position fixing.

framework, allowing increases in economy and efficiency to be made with regard to data management, system creation and control effectiveness. The feasibility of this GIS approach has been studied in a contract managed by the JRC (for DGVI) with an external study group, using IACS data sets from Portugal and Italy.

- Reinforcement of quality checks of the contractors for the control with remote sensing. After the pilot 1995 campaign (where 3 contractors were sampled), the quality checks have been run operationally by the JRC on behalf of the Member States and DG-VI, and the operation this year will be followed by similar operations in 1997 and 1998. In 1996, more than 10 contractors (out of 17) will be checked in detail.
- Initialisation of a cost efficiency study of the control with remote sensing programme for the needs of the Commission. This study involved firstly the completion of a database including all the data and results of the controls by Remote sensing since 1993, IACS statistics, different questionnaires to the National Administration followed by the definition of efficiency criteria and finally third a comparison between the on-site checks and measurements carried out without remote sensing. The first results are encouraging and the decision has been taken to complete the analysis with the 1996 data and to organise a working group on these aspects with the Member-states.

In support of these different activities during 1996, the project has made over 50 visits to Member States, always with a technical brief, and usually acting on behalf of its main client, DG-VI.

Figure 2.9 : During the workshop organised on GPS and parcel measurements, more than 10 different systems were demonstrated to delegations of the 15 Member-State administrations.

Perspectives for 1997

The main objectives for the future will be:

- increased consolidation of the IACS in the Member States : revision issues and updating of the spatial data at the core of parcel identification systems will be considered. The project will also have to be active on aspects of temporal data management. With regard to EU regulations, the year 1997 represents the first fully operational year for 12 Member States.
- Focus support on the control with remote sensing programme in the frame of "post-98" (i.e. the possible end of the co-financing by the Commission), in order to help Member States to become fully independent and operational in this area. This will involve help with training, cost efficiency analysis, quality control, simplification of methods, accuracy improvement, cost reduction and enhancement of the execution timetable.
- Development of efficient and systematic methods for quality control of orthoimage production (satellite images and aerial photography) will be an important addition to the CAP RS control activities, as well as providing support for projects in Member States.
- Synergistic activities relating to the integration of vineyard and olive tree identification will continue.
- Prospective studies on the relationship and the possible integration with other area related agricultural regulations, such as "Less-favoured areas", environmental measures, etc.
- For all these different fields of activities, the MARS-CAP project will reinforce its interest in the evaluation of the 3rd generation of very high spatial resolution satellite sensors (for example IRS1C, with a 5.8 m panchromatic pixel) and strengthen its resources and expertise in photogrammetry. More generally, orientation of all activities will also move towards the handling of geographical data using GIS and DBMS tools, and a series of new problems will arise concerning the medium and long term sustainable management of these big projects - such as IACS - often the first of their kind for the Administrations concerned.

2.7

Mars geographic extensions

Summary of Objectives

- Contribute to the harmonisation of methods and data on agricultural statistics and monitoring conditions outside the EU, the associated countries in particular.
- Make available the MARS methods, technology and know-how to countries outside the EU, mainly central and eastern Europe and Maghreb.
- Establish close collaboration with those foreign states through joint activities and training programmes.
- Promote the information flow between the EU and those countries and among the countries themselves.

1996 PROGRAMME OF WORK

1996 Milestones

March: Approval of MERA 95 Project and designation of Ispra Space Applications Institute as Programme Management Unit (PMU)

Training Course on Relational Data Bases Management

June: First meeting of the MERA 95 Steering Committee

July: Installation of CGMS (Crop Growth Monitoring System) at FOMI, Budapest

September: MERA Workshop on Soil Degradation Assessment, RISSAC Budapest

October: Former Yugoslavian Republics of Macedonia and Bosnia-Herzegovina joint MERA Project

Participation at FAO/EC/ESA/Eurimage Fourth Regional Workshop for Decision-Makers on the use of Earth Observation Data for Sustainable Management of Natural Resources, Agriculture and Environment, Sinaïa, Romania

November: MERA formulation mission to Slovenia

MERA Technical Workshop on Environmental Mapping and Monitoring using Satellite Remote Sensing and GIS, Warsaw

December: MERA 1994-1996 Results Conference, Bratislava

MERA formulation mission to Estonia

Introduction

The MERA Project is funded by the PHARE Multi-Country Environment Programme of Directorate General I (External Affairs). SAI is in charge of the technical aspects, including the definition of the terms of reference, organisation, follow-up and evaluation of the activities. Under the 1992 budget, MERA included a technical assistance component with four main sub-projects: area frame sampling survey (regional inventories), crop yield forecasting, forest ecosystems mapping and land degradation assessment, the last two falling under the responsibility of the EMAP Unit. Two other project components were included, namely hardware and software supply and specific training courses in support of the technical assistance component. Six PHARE countries were involved: Poland, Hungary, the Czech and Slovak Republics, Romania and Bulgaria. The participating institutions were mainly the Ministries of Agriculture and Environment in cooperation with specialised national institutions. The activities have now been concluded in four of the participating countries (Poland, Hungary, Slovak Republic, Romania) and are being finalised in Czech Republic and Bulgaria.

1996 Results

The area frame sampling activity was implemented, complemented by high resolution satellite data, to obtain statistics on acreage and yields for the main agricultural crops as well as information on the ownership and exploitation structure of the land. The results were accepted by the national authorities and a decision was taken on the continuity of the activity, partially financed by the country. The surface covered by this activity is 79,000 km^2 in the Czech Republic (entire country), 94,000 km^2 in Romania (40% of the territory), 31,308 km^2 in Poland (10%), 22,000 km^2 in Hungary (23%), 23,000 km^2 in Bulgaria (20%) and 6,760 km^2 in the Slovak Republic (13%). The size of the sampling segments may vary between strata and ranges from 400m x 400m in Slovenia to 1km x 1km in the Czech Republic.

The possibility of monitoring and forecasting agricultural production is also of interest to national planning. This may be achieved by using the SAI Crop Growth Monitoring System (CGMS). The necessary GIS and the databases are being prepared with the required local parameters. The CGMS system has been transferred in 1996 to the FOMI Remote Sensing Centre in Budapest and other deliveries are being prepared. The GIS output data will be agro-meteorological products and yield forecasts for selected crops.

In 1996, in addition to the work of preparation of CGMS data bases, several crop yield forecasting models have been tested in national conditions in Hungary, Poland, Slovak Republic, Bulgaria and Poland.

In 1996, an extension of the MERA Project has been proposed and approved by the Commission and the PHARE countries. This extension iscommonly referred to as "MERA 95" and has three components:

- extension of MARS activities to Latvia, Estonia, Lithuania, Albania and Slovenia;
- strengthening the capacity of the previously involved countries to assess, monitor and forecast the vegetation conditions;
- creation of a harmonised monitoring system at regional level for the rapid estimation of land cover and its changes.

In December 1996, the "MERA 1994-1996 Results Conference" was organised in Bratislava by SAI in collaboration with the Soil Fertility Research Institute (National Focal Point) and other Slovak institutions. This Conference was attended by about hundred professionals from 11 PHARE countries, coming mainly from such institutions as Ministry of Environment, Ministry of Agriculture, Statistical Office, Hydrometeorological Institute, Forestry Institute. This Conference was devoted to the presentation of the technical results of MERA 92 during specialised sessions on Environment, Regional Inventories and Agrometeorological Modelling. The Conference also included a detailed discussion of the implementation of MERA 95 Project.

From the interim and final reports, as well as from the discussions and conclusions of the MERA Conference of Bratislava, it can be concluded that the MERA Project activities have been performed at a good technical level and with a strong involvement of the national authorities, end users of the project's results.

Other complementary activities were undertaken such as the participation at the Fourth Regional Workshop for Decision-Makers on the use of Earth Observation Data for Sustainable Management of Natural Resources, Agriculture and Environment (Sinaïa, Romania, October 1996).

Perspectives for 1997

The start and implementation of the MERA 95 Project is a major activity. MERA Rapid Estimates will be implemented for the first time in central and eastern Europe, with an assessment of 1996-1997 crop area changes in 6 PHARE countries. In addition to this multi-country component of the project, national activities will start to be implemented. These activities are area frame sampling, agrometeorological modelling, vegetation state monitoring, forest ecosystems mapping and monitoring and production of a periodic synthesis bulletin on Environment and Agriculture. The performance of these activities will be supported by transfer of technical expertise, installation of hardware/software as well as thematic and software training.

2.8

Environment and major natural hazards

Summary of Objectives

- Improvement of the application of remotely sensed information in disaster management practices.
- Providing scientific and technical support to the European Environmental Agency (EEA), as foreseen in the Council Regulation creating the Agency; assisting the EEA to formulate scientific requirements and to utilize research results for improving its information provision activities. This overall objective is mainly translated in the participation of the SAI in the European Topic Center on Land Cover as the leading partner in charge of the Research and Development task.
- Estimation of quantitative changes of land cover and/or land use in European coastal zones (LACOAST project).

1996 PROGRAMME OF WORK

1996 Milestones

January: Official start of the activities on Environment and Natural Hazards

February: Meeting EEA and Steering Committees of European Topic Centers

March: Meeting for the final evaluation of the prototype computer system to update the CORINE Land Cover database. Training of IGN Spain (ETC/LC partner) on the use of the same prototype.

Workshop on the development of the CORINE Land Cover database (nomenclature) in Alpine (mountainous) areas, Vienna

June: Technical workshop on Spatial Generalisation, U.K.

July: Common workshop with ESA, Council of Europe (EUR-OPA) and DG XII-D4 on Space Techniques and Major Hazards.

Kick-off meeting of the LACOAST project dealing with land cover changes in coastal areas

August: Signature of the Memorandum of Cooperation between SAI and MDC Sweden, which governs SAI's activities in the European Topic Center on Land Cover (ETC/LC) as the partner in the Steering Committee in charge of the R&D task

November: Workshop on Indicators for Coastal Zone Characterisation and Management, Lisbon.

December: Submission to the EEA of a draft of the Technical and Methodological Guide for the Updating of the CORINE Land Cover Database.

Introduction

The work described here represents a new activity for the AIS Unit. This new area of applied research focuses on three main themes natural hazards management, support to the EEA for land cover and the LACOAST project.

The overall objective of the "Hazards" activity is to study the improvement of existing disaster management practices (specifically management of natural disasters like forest fires, floods and droughts) through the use of Earth Observation (EO) derived information. Processed space data integrated with other sources of information within a geographic information system are thought to complement ongoing management practices before (prevention phase), during (crisis phase) and after (damage assessment phase) a natural disaster.

The EEA established the European Topic Center on Land Cover (ETC/LC) to develop, update and promote the CORINE Land Cover database of Europe. The ETC/LC is a consortium, with MDC Sweden as the main contractor. SAI is a partner of the ETC/LC, member of the Steering Committee together with the CNIG (Portugal) and MDC (Sweden) and it is in charge of the Research & Development related to the Land Cover topic.

The aim of the LACOAST (Land cover changes in European coastal zones) - project is to estimate quantitative changes of land cover and/or land use in European coastal zones especially due to human activities. The coastal zone has been defined as a strip of 10 kilometers from the shoreline. It uses the CORINE Land Cover database over coastal zones. The project is being developed with the CEO (see chapter 7). It is developed in close collaboration with users (DGXI Environment, Nuclear Safety and Civil protection and the European Environment Agency, EEA).

Natural Hazards

After a first assessment of current user requirements two activities were defined: co-ordination and implementation of pilot projects.

Co-ordination activities:

Co-ordination in 1996 referred to both SAI internal activities related to natural disasters, as well as representation of the Institute in international activities (e.g. Space fora related to disaster management). In addition, support is given to the services of the Commission dealing with disaster management when competence in space techniques is required.

In July 1996 a workshop on *"Space Techniques and Major Hazards"* was organised together with the Council of Europe - Secretary of the Open Partial Agreement on Major Hazards, the European Space Agency - Directorate on Strategy, and the European Commission - DG II / D4. The workshop concluded that existing structures and space activities are not satisfactory to meet the users information and coordination needs. A proposal for setting up a European Program on Major Hazards was initiated.

Implementation of pilot projects:

To avoid duplication of work, a survey on past and on-going projects on forest fires, flooding and droughts was performed. Pilot projects on forest fires, floods and droughts were begun during the year. In each field standard methodologies will be developed for the prevention phase and the relief phase (damage assessment) of disaster management. After the development and testing phase, these methodologies are to be applied to large areas.

Forest Fires: In the frame of shared cost action projects with various Mediterranean partners, the development of Earth Observation based methodologies for fire risk assessment have been started. In addition, the possibilities to apply Earth Observation in the fields of fire detection, fire fighting and fire inventory as well as in the fields of mapping and assessment of the effects of large fires have been discussed. The expected outputs are fire risk maps at local and Mediterranean scale, fire growth maps and burnt area maps.

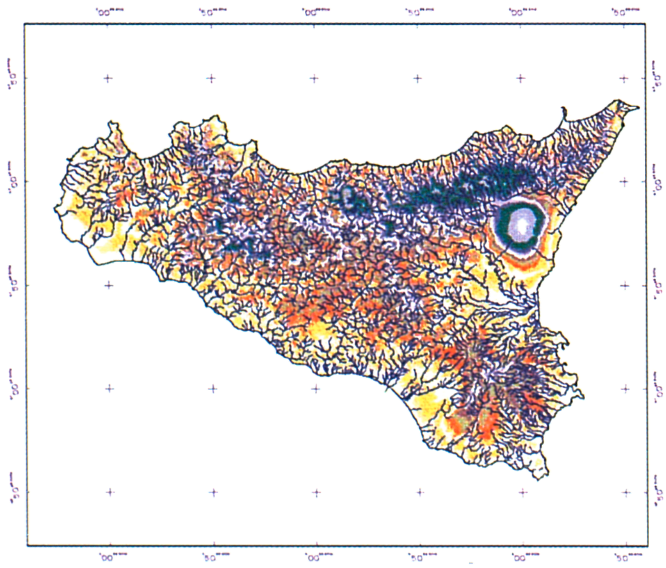


Figure 2.10 : Hydrographic database for Sicily.

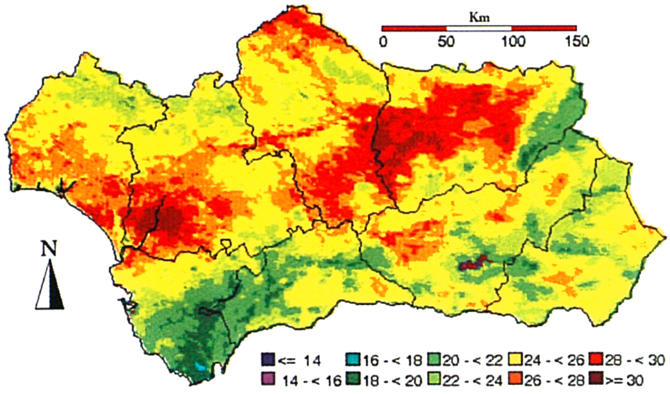


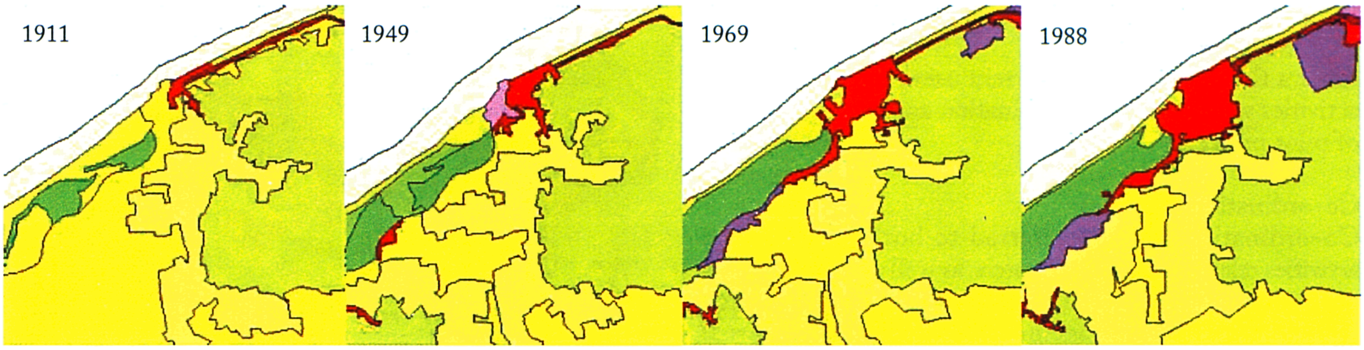
Figure 2.11 : Air temperature (°C) data base Andalusia.

Droughts: The activities have concentrated on the definition and development of an adequate working strategy. In this context an extensive literature search and analysis has been performed. In order to support the test and development of methods, databases have been set up for Sicily as well as Andalusia (Figure 2.10). Discussions and contacts are underway for the set-up of equivalent databases for other regions in Central and Eastern Europe. Contacts have been established with several authorities in the field of drought monitoring and discussions concerning information needs for drought monitoring as well as concerning interests for future scientific collaborations have been performed. In addition, the use of SPOT/HRV and Landsat/TM data for the preparation of hydrologically relevant landcover maps has been tested.
Specific research tasks have been performed concerning the regionalisation of air temperatures in collaboration with the Universitè Laval, Québec and the Ministry of Environment (Consejería de Medio Ambiente, CMA) in Andalusia Figure 2.11. The results obtained are interesting to such an extent that the CMA is willing to implement them in the environmental monitoring system of Andalusia for operational testing.

Floods: A feasibility study was performed on the detection of areas of hydrological risks using remote sensing data. Applying a Digital Elevation Model, the hydrological network and the water heights in the network, the flooding of the Var river (southern France) was simulated. The simulation model was calibrated with real data. By combining the output of the various simulated scenarios with actual land use data, information about possible flood damages could be deduced.

Support to EEA / Land cover

SAI participated in meetings at several levels: ETC/LC Steering Committee, Advisory Committee and Consortium meetings, as well as in meetings with the EEA Scientific Committee or between the EEA and all the European Topic Centers. We were asked to participate in meetings



Corine land cover changes Area of wenduine • derived fron topographic maps scale1: 25.000

Land cover legend

1.1.2	Discontinuous urban fabric	1.1.2	Complex cultivation Patterns
1.2.2	Road and rail networks and associated land	1.2.2	Natural grass land
1.4.23	Spot facilities	1.4.23	Transitional woodland-shrub
1.4.24	Camping	1.4.24	Beaches
2.1.1	Non-irrigatedarable land	2.1.1	Dunes
2.3.1	Pastures	2.3.1	Sea and ocean

Figure 2.12

and Workshops organised by other Topic Centers to give the contribution of Land Cover for integrated uses of European databases for Environmental assessments. It was mainly done with the ETC on Marine and Coastal Environment and the ETC on Nature Conservation.

SAI participates also in the elaboration of the Technical Work Programme under the 1995 and 1996 subventions. Four quarterly reports were prepared and the draft 1996 Annual Report of the ETC/LC.

A draft proposal for the Land Cover data policy was prepared. It starts to be discussed with other ETC/LC partners and the EEA.

The defined Work Programme for the Research and Development Task was accomplished as foreseen for 1996. Studies were launched and monitored for 5 sub-tasks:

Development of Environmental Indicators derived from the CORINE Land Cover database (CLC) in combination with other sources of information. It was mainly linked with the needs for nature conservation.

Spatial generalisation, to study and to establish a method which permits spatial generalisation to generate or to compare with CLC for further integration. The priority was given to the necessary methods to finalize the CLC database in countries where the database is not complete.

Updating the CLC database, the global assessment of the methodology and Prototype computer system developed by AIS to update the CLC database was achieved. The draft Technical and Methodological Guide for the Updating of the CLC database was presented to the EEA and its publication will occur early 1997.

Regional nomenclature workshops and pilot projects, the objective was to define a nomenclature at 4th and 5th levels for different European regions. Two workshops were held: one for Alpine (mountain) areas, for which the Alpine Observatory was invited and participated, another on nature conservation with the participation of the corresponding Topic Center.

The LACOAST project

Work for the LACOAST in 1996 was mainly of a planning nature. A preliminary study performed by the Belgian team demonstrated the feasibility of the planned work, (Figure 2.12).

Perspectives for 1997

The 1997 activities will for fire will concentrate on a forest fire risk mapping demonstrator, forest fire propagation modelling and Burnt area mapping.

Droughts activities will focus on the development of a methodology for the detection and quantification of drought events using the databases set up during 1996.

Flood risk assessment work will continue to integrate remotely sensed information such as land cover and digital terrain data into existing run-off models. This will be augmented by work on flood damage assessment.

Activities within the ETC/LC will be continued. The R&D task will be tied with the needs coming up from the other tasks and conform with the priorities defined by the EEA.

For the LACOAST project in 1997 it is foreseen to estimate land cover changes on samples of the European coastal zones for the years 1955, 1975, 1985, 1995.

2.9

The European Soil Bureau

Summary of Objectives

- data needed for numerous purposes by the Commission or other external bodies.
- To respond to the needs of the Commission, providing information necessary for the programs of the DGs.
- To develop and implement policy and guidelines for the production of harmonised, and therefore compatible soil data.
- To develop and implement a policy for the distribution of information concerning soils, with the objective of favouring exchange of data without compromising the interests of the producers.
- To develop and distribute the tools facilitating the exchange and use of soil data.
- To establish links with international bodies, such as FAO and UNEP, in order to assure a reciprocal flow of information.

1996 PROGRAMME OF WORK

1996 Milestones

March: Soil Information System Development Meeting. Creation of the European Soil Bureau (ESB), taking over the activities of the Soil Information Focal Point (SIFP)

June: Meeting of the Information Access Working Group (IAWG)

Finalisation of the Information Access Policy of the European Soil Bureau.

First meeting of the Advisory Committee of the European Soil Bureau with official representatives of the EU Member States

July: Release of Version 3.2 of the Soil geographical Database of Europe at Scale 1:1,000,000

September: Kick-off meeting of the project 1:250,000 soil database of the "Pianura Padano-Veneta" in collaboration with the Regional authorities of northernItaly

October: Definition of the new "Georeferenced Soil database of Europe at Scale 1:250,000".

Creation of the new "Soil Hydraulic Functions" working group within the ESB

November: Workshop "Land-Information Systems: Developments for Planning the sustainable use of land resources"

December: Meeting of the Inter-DG Coordination Group on Soil Information

Introduction

The European Soil Bureau (ESB) was created in 1996 as a new body within the European Commission. Its aim is to carry out scientific and technical duties in order to harmonise soil information relevant to Community policies, its relevant General Directorates (DGs), to the European Environment Agency (EEA) and to concerned institutions of the Member States. It reinforces the work which has been done in the frame of the Soil Information Focal Point (SIFP). It has been created following the recommendations of the European Heads of Soil Survey in the EU Member States and the Inter-DG Co-ordination Group on Soil Information of the European Commission.

1996 Results

Four working groups are currently active within the ESB:

- The 1:1,000,000 **European soil database** group has already been operating for many years, well before the creation of the ESB. It has been the driving force of an European joint effort by many soil scientists from different countries. The developed soil geographical database has presently four parts: (1) the meta-database, (2) the so-called geographical database, (3) the soil profile database, and (4) the knowledge database. The geographical extension currently covers (Version. 3.2) the EU Member States (excluding Sweden, Finland and Austria) and the Central and Eastern European countries (Poland, Czech Republic, Slovakia, Hungary, Romania and Bulgaria). It can be accessed (read-only) on the World Wide Web through a GIS-WWW gateway and is reachable via the following address: http://taws08.jrc.it/gis-gateway/ gateway_main.html.

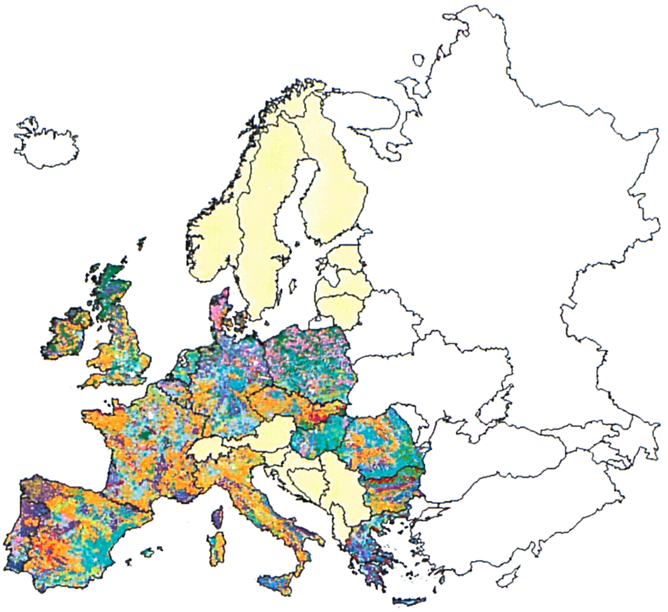


Figure 2.13 : Geographic extension of the Soil Geographical Database of Europe at Scale 1:1,000,000 Version 3.2. In yellow are countries to be included by 1998.

- The **Information Access Working Group (IAWG)** turned out to be one of the most important within the ESB, as it is in charge of the development of an European policy for the access to soil databases. The general aim of the group has been to develop guidelines that insure the maximum protection of the data ownership together with regulated access for all the potential data users. The Information Access working group developed the guidelines that are a major breakthrough in European data access policy. The key statement is that data ownership and copyright remain with the Contributor. This means that the data supplied to the ESB by the contributors for the creation of the European soil database are owned by the contributors and not by the Commission. On the other hand the principle of regulated access to the data by everybody is reinforced. The combination of these two statements produces a data access policy that maximises database access and use, and safeguards the intellectual property of the Contributors. The licenser of all the soil data is the European Commission through its European Soil Bureau and is the focal point for data licensing and distribution. Data is leased for a limited time and not sold. Data is charged according to a fixed price matrix. The data to be distributed at the beginning of 1997 are the Soil Geographical Database of Europe (Version 3.2) and the Soil profile Database of Europe (Version 1.0). The adopted price matrix differentiates the cost of lease of data according to the use. The minimum charge (cost of handling) is applied to contributors and non-profit organisations for internal use. Charges are applied in the case of external use by these organisations. Maximum charging is applied to full commercial use by private organisations.

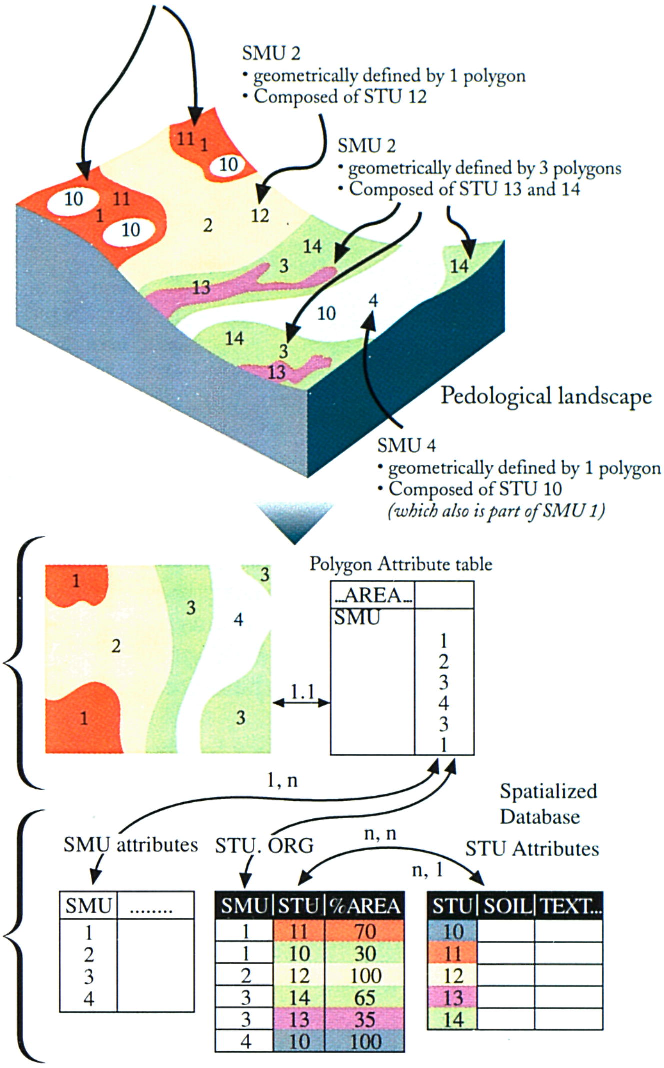


Figure 2.14 : Information organization in the Soil Geographical Database of Europe.

- The **1:250,000 working group** represents the future of the ESB. It is working on the design and construction of the new European soil database at scale 1:250,000. It has been established following a feasibility study by the DG XI (Environment) in 1993, that recommended the creation of such a database for future environmental applications within the EU. Given the low availability of soil data suitable for preparing a more detailed soil map of Europe, it was determined that "a wall to wall soil map" or soil database could be accomplished only in the long term, but a recommendation was made to carry out studies in small pilot zones with a high coverage of data, with the aim to develop a methodology, a common legend and a common database useful for the final database at scale 1:250,000. This principle was also endorsed by the European Environment Agency. In order to start the project, a working group was created within the ESB. It is charged with the preparation of the Manual of Procedures, the delineation of the pilot areas and the overall scientific supervision of the project. From the operational point of view the database will be created in selected pilot areas co-ordinated by region for the territorial correlation of each project. The selection of the first pilot area already started with the delineation of an area covering the North-Italian quaternary plains.

- The **soil hydraulic parameters working group** has been established independently of the ESB, financed through a Human Capital and Mobility Network. Only during its second year of work did it apply to be included in the activities of the ESB, as it is concerned with a soil hydraulic parameters database linked to the 1:1,000,000 soil database of Europe. The database will be distributed in its final version through the ESB according to the same data access procedures.

Perspectives for 1997

New EU countries and neighbouring countries are expected to be included during the coming years. A major challenge is to integrate the various databases (profile, pedotransfer rules, meta-database, reference catalogue, etc.) into a single European Soil Information System (EUSIS). It is expected to complete such a system by 1998 covering the complete EU and the Central and Eastern European countries (CEEC).

10

Work for third parties

Summary of objectives

To provide a service for external customers.

1996 Milestones

January: ISIS Kick-off Meeting

March/June: Setup of basic layers of the POP SICILIA GIS

April/July: OLIWIN Model design - crop, meteo and soil data gathering - GIS and database preparation - interim report

June: Installation of the Preliminary ISIS Demonstrator at JRC

POP SICILIA Field work in the Anapo catchment area

August/December: OLIWIN Model implementation - first tests and calibration - statistical validation on European scale data

December: Submission of the final POP SICILIA report and GIS. Conclusion of the project October: ISIS Key User workshop

1996 PROGRAMME OF WORK

The HYDRE Project

The Mediterranean region is characterised by strong seasonal and inter-annual variability in precipitation, giving rise to regular droughts with adverse effects on the ecosystem and its hydrological resources. Moreover, the last decades were characterised by an increasing demand for water, resulting in serious problems for adequate water provision during dry years. In response to this situation, the Confèrence des Règions Pèriphèriques Maritimes (CRPM) and the EU Directorate General of Regional Politics, DG XVI, launched the HYDRE (Monitoring Hydrological Resources in Mediterranean Regions) project. The project can be considered an excellent example, where methods and databases developed for the Advanced Agricultural Information System were adapted to a different environmental application.

While the project as such has been concluded in December 1995 a few remaining tasks were concluded in early 1996 and further research issues are under discussion with several of the regions participating in HYDRE.

Activities and Results

Within the HYDRE project, the AIS Unit has been collaborating with the regions of Andalucia, Languedoc-Roussillon, Sardinia and Sicily to develop and implement an adequate methodology and to promote the establishment of a regional network for the real-time monitoring of hydrological resources in the Mediterranean area. Major tools are agro-meteorological models and daily remote sensing data from the NOAA-AVHRR sensor.

The project has led to the establishment of extensive databanks for each of the participating regions. Collected information includes data on administrative units, topography, land cover, regional crop varieties (phenology, water requirements, etc.), soil characteristics, drainage patterns and daily meteorological conditions for high density networks. These data were then prepared for the use with the agro-meteorological modelling tools developed in the MARS Project, which had to be adapted to employ high resolution data. In addition, a specific water balance model was developed for perennial crops, such as olive and citrus trees. In addition, daily AVHRR data have been pre-processed and parameters such as various vegetation indices and the surface temperature have been analysed for each region.

From April 1993 to December 1994, the project issued a monthly bulletin containing maps on the regional distribution of various meteorological parameters, the development status of the most important crops as well as the vegetation index and the surface temperature derived from satellite measurements. All data processing, starting from the collection of daily raw data to the elaboration of the final maps, was handled by the AIS Unit. With the installation of a full system in each region in 1995, the preparation and further development of such a bulletin is now within the hands of the regional authorities.

In 1996 further assisstance was given to the regions and a specific training course on the use of the various software packages installed was held at Ispra.

As a result of the close collaboration with the regions, various common scientific activities emerged. Examples are projects on the regionalisation of agrometeorological parameters and in the field of drought monitoring.

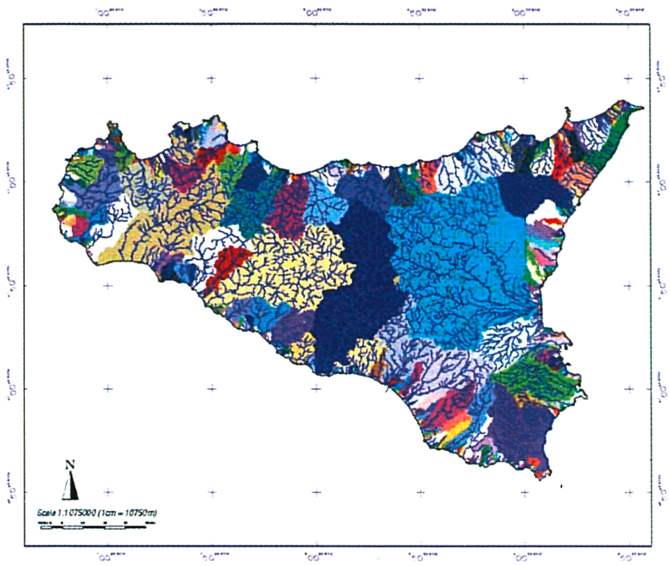


Figure 2.15

The POP Sicily Project

Water is an important and increasingly scarce resource in Sicily. Growing demands from the various water users, such as agriculture, industry and population, have led to a situation where the quality and quantity of water requires constant monitoring. The use of modern techniques of data acquisition, storage and analysis is the only possibility to cope with this need.

In the frame of the Programmi Operativi Plurifondo (POP), the AIS unit has been collaborating with two other JRC institutes and three Sicilian universities in a project on the development of a Decision Support System for the sustainable management of hydrological resources in the region of Sicily (POP Sicily - Project A). More specifically, the unit was responsible for the setup of a relevant geographical information system and for the integration of remote sensing derived information.

Activities and Results

An important basis for the developed decision support system is a geographical information system (GIS) keeping all necessary data in an easily accessible and congruent format. The AIS Unit has been responsible for the set up of the GIS and to collect the relevant data. In addition, the possibilities to derive information from remote sensing data had to be evaluated. This concerned the use of high spatial resolution data such as SPOT/HRV and Landsat/TM for land cover mapping at the catchment level, and low spatial resolution data from the NOAA-AVHRR sensor for the monitoring of relevant surface parameters over the whole island.

Within 1996 a relevant GIS has been developed. Available data include a digital soil map and a digital terrain model (DTM) for the whole of the island, as well as more detailed information for the Anapo hydrological basin in the Eastern part of Sicily. In parallel, the possibilities to set up a real-time meteorological database for Sicily have been further evaluated. The HYDRE database served as a starting point in this respect.

Various secondary data layers have been retrieved from the DTM, such as slope and aspect maps or the limits of the hydrological basins in Sicily (Figure 2.15) as well as of the sub-basins of selected watersheds. All data as well as the various processing steps have been extensively documented.

In parallel, the possibilities to extract hydrologically relevant landcover data from high resolution SPOT/HRV and Landsat/TM data have been evaluated. As a result a landuse/landcover map for the Anapo basin has been prepared keeping hydrologically relevant landcover classes. The use of NOAA AVHRR data for the monitoring of surface conditions over the whole of the island has been evaluated and some examples have been given for the combined analysis of AVHRR and meteorological data (Figure 2.16) A more operational analysis, however, was prevented due to the lack of recent meteorological data. Consequently, recommendations have been given for the set up of such a database and possible data providers have been identified.

The ISIS project

ISIS is a Shared Cost Action technology demonstration project. Its funding is provided by the ISIS Consortium partners, (a partnership between industry and several international organisations) and by the ESPRIT program of the DG III (Industry).

The ISIS Project has a duration of 30 months during which it will design and build a data server system that will allow users to select the precise data they require from large scale Satellite Image Data archives - including part scenes. This is expected to give major benefits to end users and data providers alike, such as:

- A reduction in the the cost of image data, by allowing data providers to create innovative pricing schemes based on part scenes - for example pricing by pixels;

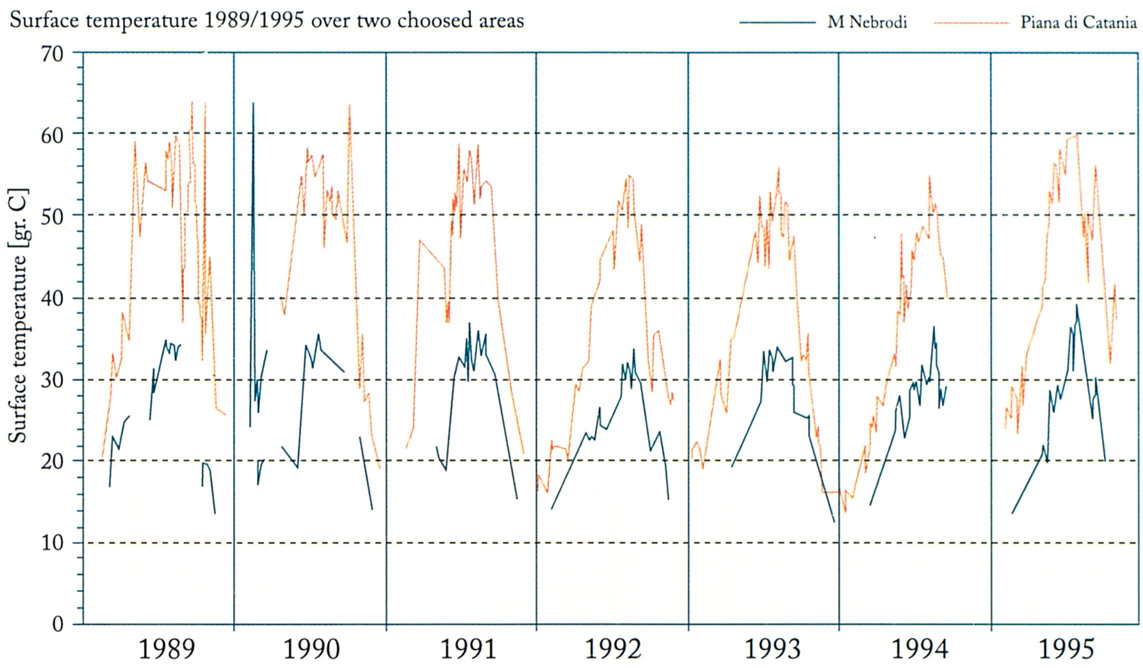


Figure 2.16

- The ability to deliver satellite imagery to the end user over affordable European data network connections;
- The data selection process will be highly interactive. Users will be able to find the exact information they need, quickly;
- The server will support searches and data selection criteria based upon image content;
- Data from different satellites will be supported. Users will be able to access the best data for their application easily;
- ISIS will allow image processing systems to be embedded into the server. The facility will allow data products to be tailored on the fly for specific end-user applications. The benefit to users will be a reduction in costs and expertise needed to exploit the data.

ISIS will achieve these advantages through the application of high-performance computer and networking technologies to the problem of Remote Sensed data search and delivery. The project will proceed by building a series of technology demonstrators defined, in part, by real end-user requirements.
ISIS Development will proceed in 3 major stages:

Preliminary Demonstrator
V0 Prototype - mid 1997
V1 Prototype - early 1998

The Preliminary Demonstrator system is a simple WWW server designed to outline the basic ideas of ISIS. With this knowledge it is hoped that the evaluators will be able to specify their requirements for the Prototype phases in the light of some experience. The Preliminary Demonstrator must not be considered an ISIS Prototype.
The V0 and V1 Prototype systems will implement the full ISIS functionality. By building two systems the Project can take advantage of operational experience with the V0 Prototype before building the final V1 Prototype in 1998.

Whilst these Prototypes will not be part of any existing User Services, they will provide a technological basis that will be reused in future systems.

Activities and results

The JRC/SAI's main activities for ISIS have been:

- collection and description of User Requirements for ISIS. JRC/SAI was co-responsible for this activity, the Work Package manager being ESA/ESRIN. This work has culminated in the production of a User Requirements Document that will be subject to review by the EC during January 1997;
- an exploration of the Earth Observation product market, in order to define interesting market segments for ISIS. The outcome of this activity will also be presented for review in January 1997;
- definition and description of the applications to be supported by the Preliminary Demonstrator, and, in part, by the V0 Prototype;
- development of the ISIS Website
- Operation, Administration and Maintenance (OA&M) of the ISIS PD.

OLIWIN

The methods for the estimation of grapevine and olive oil at the regional and national level that are presently in use in the various Member States where these crops are grown are estimates on the basis of statistical surveys (carried out at the level of producers or cooperatives) or on the basis of farmers or cooperatives declarations. They provide production estimates with the inconveniences of a lack of comparability of the sampling and survey methods and of the corresponding precision of the results, and with a timeliness of the availability of the information.

The OLIWIN project will use simple agro-meteorological model at European level to provide timely information on expected wine and olive oil productions, which will be reliable and precise enough to serve as an early, but provisory source of information for the decision making, planning, etc. and which at the same time will be independent from uncertainties in the provision of information by national or regional administrations.

1996 Results

The project is planned to be carried out within one year with first results in springtime 1997. After the first six months, OLIWIN has implemented a European GIS and database with meteo data and soil data. Part of the crop data (vineyard and olive tree) has also already been stored in order to begin some model calibration and statistical analysis. Part of the crop data has still to be collected next to European experts, universities, regional administrations. This crop data should allow an improvement of the quality of the results.

Perspectives for 1997

- The POP SICILIA project has been concluded in 1996. Further collaborations with the region of Sicily are however pursuing on the combined use of meteorological and remote sensing data for the detection and monitoring of drought conditions.

- During 1997, the JRC/SAI activities for ISIS will concentrate on the collection and description of algorithms to be used for the V0 (possibly V1) Prototype and the initiation of the important Work Package 700 *"ISIS Concept evaluation and dissemination"*, for which JRC/SAI is co-responsible.

- The first phase of the OLIWIN project should be concluded about April 1997. A first Bulletin information about the crop state will be published about the same period. During a second phase study, OLIWIN will focus on model and system improvements and area enlargement. The bulletin information should be supplemented by potential production and yield information.

- The REACT_B project (Re-engineering of the Rapid Crop Area Estimation Activity (Activity B) of the MARS - project) should lead to the design and implementation plan of an information system which should allow for the rapid estimation of crop area changes at the level of the European Union, its Member States and principal regions. The AIS has been operating since 1992 a pilot version of a decision support - information system on agricultural production estimation in support to the institutional activities of the Directorate-General VI-Agriculture (DGVI/A/2) and the European Statistical Office, EUROSTAT. This information system responds to the initial requirements of the DGVI/A/2: The REACT_B project is called a re-engineering project because it will start by recovering as much as possible from the design of the legacy system, being the Activity B of the MARS project, while at the same time encapsulating in its design the necessary functionality to respond to the changing requirements of its end-client, the DGVI/A2

- Work in 1997 will also begin on MARIE-C, which stands for *"Monitoring of Agricultural Resources in Europe"*. It is a Shared Cost Action carried out in the framework of the FAIR Programme. The partners are EARS from the Netherlands (Ingenieursbureau voor Environmental Analysis and Remote Sensing), the Applied Remote Sensing Laboratory of the School of Agriculture, Food and Environment from the Cranfield University (United Kingdom) and the Agricultural Information Systems Unit of the JRC Space Applications Institute. The project, with a total duration of two and a half years, expects results in the following fields:

  - A new, validated methodology for METEOSAT based crop yield forecasting in Europe and in the Mediterranean Region;
  - A new, validated methodology for the use of NOAA derived indicators ins statistical regression models for crop yield forecasting;
  - An assessment of the precision and timeliness of the yield estimates and forecasts obtained from METEOSAT and/or AVHRR against the forecasts obtained from other sources (e.g. the actual MARS Advanced Agricultural Information System, Eurostat, National Statistical Services, etc.).

Environmental mapping and modelling

The research and development work carried out in the Environmental Mapping and Modelling Unit (EMAP) is concerned with the application of remote sensing to environmental issues, primarily regarding soil and vegetation in Europe. It concentrates on two main themes: (a) mapping and monitoring the main permanent large ecosystems of Europe, i.e. forest and natural grassland, and (b) developing monitoring and protection methods based on the combination (through GIS) of remote sensing and dynamic models, applied to ecologically sensitive regions, such as the Mediterranean basin.

Associated with these thematic issues, the Unit continues the development of advanced methods of image and data processing, such as automatic classification and mapping, map generalisation and parallel computing. This effort is necessary if the full potential of remote sensing for environmental mapping and monitoring is to be exploited in connection with the continuous development of sensor performance and computing methodology.

During 1996, EMAP´s thematic activities specifically addressed temperate forest monitoring via the FIRS (Forest Information from Remote Sensing) Project, and Mediterranean land degradation, including landslide detection.

Soil and vegetation degradation modelling in Mediterranean environments continued to address the problem of adapting spectral mixture analysis methods to diversified landscapes. Following Southern Spain, Italy (Benevento), continental Greece (Pelopponese) and Southern Tunisia, investigations also began in central Crete and Languedoc-Roussillon (France). Methodological steps included the development of an environmental spectral library concept and studies aiming at the definition of regional scale desertification indicators. Exploratory research on the use of new and future sensors encompassed airborne imaging spectrometry data for correlating soil mineralogical/chemical abundances to degradation states and the simulation of the use of SPOT4-VEGETATION instrument from Landsat TM data.

Within the framework of the FIRS Project, the study on the design of a system of nomenclature for European forest mapping was completed, together with the definition of methodology and evaluation of results for mapping European forest with AVHRR data. The same was done for the connected activity launched in 1995 on mapping European land occupation in broad classes, with AVHRR.

The forest component of the PHARE-MERA Project applying the FIRS methodology was also completed for the Czech Republic, Hungary, Poland, Romania and Slovakia. It included the use of the Silvics software developed within FIRS for automatic forest stand delineation by segmentation methods.

The third party work for the Sicily Region was also completed as required at the end of the year. It represents the achievement of an ambitious undertaking on erosion modelling and coastal evolution monitoring. In particular, it involved the assessment of the spatial distribution and intensity of soil degradation and erosion in a large catchment area (4200 km^2) by three different methods, with reasonable agreement among the results.

The activities on Advanced Methods noticeably expanded in 1996 in order to fulfill commitments connected to shared-cost and support to the Commission actions. They were mainly dealing with:

- connectionist methods for neural computing (concerted action);
- benchmarking neural network parallel hardware systems for remote sensing applications: CSC DG III action mainly concerned with the evaluation of the Siemens-Nixdof SYNAPSE-1 neuro-computer;
- the start of (a) the FLIERS SCA on fuzzy neural networks for mixed landscape analysis, (b) the CSC to EUROSTAT on the use of neural networks for improving land use statistics, and (c) the ISC to DG III-F on the development of a European GIS research strategy.

Coming years (1997/98) will see an increase in EMAP´s activities in Mediterranean land degradation and desertification monitoring with the start of the CAMELEO Project. The same will happen within the FIRS frame with the CEO-funded FMERS Project on forest area and composition mapping and statistics. Similarly, EMAP will open a new field of activity on urban land use mapping and statistics within the ATLAS Project funded by CEO and later on by EUROSTAT and DG XVI.

3.1

Desertification monitoring and land degradation mapping in the mediterranean basin

Summary of Objectives

- Definition of remote sensing based indicators of ecological changes for the production of maps suited to desertification monitoring, mitigation and land management in the Mediterranean
- Assessment of ecological changes over the archiving period of existing earth observation systems
- Interpretation of change according to land use and experimental modelling of environmental change
- Development of a comprehensive processing chain dedicated to land management, which will be able to accommodate future enhancements (new types of sensors, data and algorithms)
- Definition and implementation of a *"Satellite Observatory"* for desertification monitoring in the Mediterranean region

1996 Milestones

January: MEDALUS III contract start

March: DeMon 2 contract start

May: Setup of DeMon and MEDALUS data exchange server

July: Interdisciplinary field campaign in the La Peyne test site, Montpellier (F)5 participating research institutes

September: Submission of CAMELEO proposal to the INCO-DC programme

October: Interdisciplinary field campaign in Crete (GR), 6 participating research institutes.

Publication of DeMon 1 Final Report

December: First results of regional vegetation type classification in the European Mediterranean

1996 PROGRAMME OF WORK

Introduction

In view of the European Commission's interest to monitor and mitigate land degradation and desertification phenomena in the European and non-European Mediterranean countries, EMAP is investigating the potential of operational Earth observation satellites for mapping and repeated monitoring of vegetation and soil characteristics in the region. In previous experiments, approaches based upon optical remote sensing data, GIS and environmental modelling have been developed, and successfully applied to wider areas in the European Mediterranean.

In 1996 the requirements for the design of an operational satellite observatory for Mediterranean land degradation monitoring were investigated within a suite of international research projects which are expected to provide important inputs to pilot studies for an overall conceptual framework for monitoring changes in Mediterranean ecosystems on the long term with Earth observation systems. For the northern (i.e. European) Mediterranean this concept is being developed on test sites in S-Spain, S-France, Sardinia, Sicily, N-Peleponnese and Crete, together with the project partners of the shared cost action projects DeMon 2 and MEDALUS III, both being funded under the European Commission's Environment and Climate programme. For extending the monitoring approach to the southern Mediterranean (i.e. North Africa) a working group was formed involving three European and four North African partners. This consortium brings together researchers from Algeria, Egypt, Morocco, Tunisia, Italy, France and of the JRC and has defined a joint project named CAMELEO (**C**hanges in **A**rid **M**editerranean **E**cosystems on the **L**ong-term through **E**arth **O**bservation).

This fundamental, application oriented work programme is supplemented and supported by exploratory research activities. These include the continuation of the EMAP Mediterranean field spectrometry programme and the investigation of the potential of new airborne and spaceborne systems, such as imaging spectrometers and SPOT VEGETATION, for environmental mapping and monitoring in Mediterranean ecosystems.

Results

The 1996 work programme and its achievements were mainly related to the preparation and implementation of the shared cost action research projects. A second focus were the studies on the application of forthcoming, advanced remote sensing systems to land degradation mapping in the Mediterranean basin.

Competitive Research Projects:

In the beginning of 1996 the contracts for MEDALUS III and DeMon 2 were signed and the projects implemented according to the proposed work schedules. Furthermore the CAMELEO concept was completed under the scientific lead of EMAP and submitted to the DG XII programme on International Cooperation with Developing Countries (INCO/DC).

DeMon 2: Within DeMon the major objective of EMAP is the enhancement of standardised thematic interpretation concepts of reflectance data by adapting them to regional physiographic conditions of larger Mediterranean ecozones. In this context the 1996 key issue was the development of a regional, environmental spectral library concept and the initiation of the practical realization of the data base structure. Furthermore two extensive radiometric field campaigns were conducted in the new DeMon test sites La Peyne (S-France) and Central Crete (GR).
A spectral library supporting an optimally standardised exploitation of spectral information from remote sensing data at regional scale must not only include just a collection of reflectance spectra, but should also parameterise specific spectral characteristics of the sample and relate these to relevant physical/chemical properties of the reflecting surface.

For libraries of natural materials such as soils, rocks, green and dry vegetation components, to be used in a regionalised interpretation scheme, additional elements are required for parameterising spectral characteristics, which are normally different from parameters being typically used in conventional mapping e.g. of soils, rocks, land use and natural vegetation. Furthermore the relationship to specific physiographic and ecological background conditions should be given to link the data to models e.g. of soil development or vegetation dynamics.

MEDALUS III: In the framework of the MEDALUS III project, EMAP is leading the project module on regional physical indicators of desertification. Key indicators for desertification monitoring and modelling are changes of semi-natural vegetation and agricultural land use over time at regional scale. For the development and refinement of regional scale desertification indices and models, better estimates of vegetation cover are required e.g. for comparing model derived potential cover and current actual cover. The recent practice to apply standard classification algorithms to this purpose suffers from the fact that the sensors currently providing regional coverage (e.g. AVHRR, Meteosat) lack the spectral range and spatial resolution which are required to achieve reliable cover/density estimates of scarce vegetation communities typically appearing

Soils:

- Content of mineral components causing spectral absorption features: e.g. Fe-oxides, carbonates, clay fraction,
- Development of related features (FWHM, depth, asymmetry, etc.)
- Spectral shape parameters in relationship to organic matter content and surface texture parameters
- calculated munsell soil colour from visible channels in relationship to organic matter content and surface texture parameters (e.g. agglomeration, crusting, stoniness)
- background lithology

Rocks:

- spectra of fresh and natural surface (i.e. weathered)
- major mineral components
- Development of related features (FWHM, depth, asymmetry, etc.)
- munsell colour term as above

Vegetation:

- spectra of typical Mediterranean species (full plant) and canopies, plus measurements of green leaves
- dry vegetation components i.e. dried leaves, leave litter (mixture of dry and partly decomposed plant components), bark, wood etc.

External parameters:

Each sample of above-mentioned materials should be linked by the geographic coordinates of the sample point and to so-called external parameters that may be collected during sampling campaigns and/or from external data bases e.g. GIS layers. Key parameters are:

- sample point coordinates
- slope position of sample point, slope direction/exposition, inclination etc.
- background lithology
- regional eco-zone

Table 3.1 : Major parameters of the regional spectral library concept.

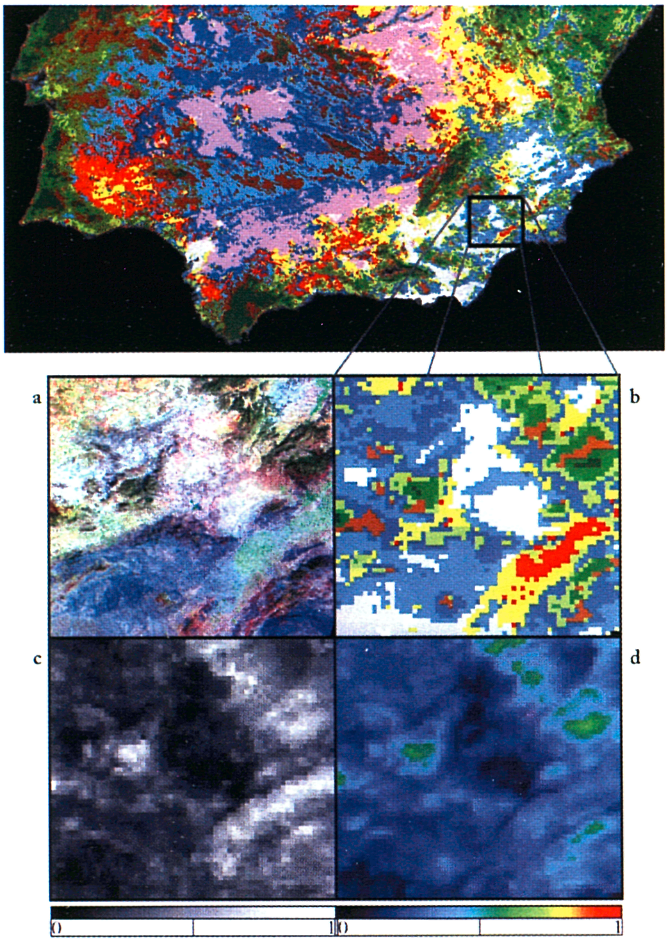


Figure 3.1 : Unsupervised vegetation type classification and vegetation density assessment of the S-Iberian peninsula.

in semi-arid areas. To improve this situation and to provide the MEDALUS regional modelling group with rapid coverage estimates of current regional vegetation types, EMAP started to implement an improved regional scale vegetation type classification and cover density assessment for the southern half of the Iberian Peninsula, based upon unsupervised classification and spectral mixture analysis (SMA) of annual time series of AVHRR data and reference Landsat-TM scenes as demonstrated in Figure 3.1.

Exploratory Research towards the Application of New Sensors:

The usefulness of imaging spectrometry for land degradation and desertification assessment has already been successfully demonstrated in the prior DeMon-1 project and is further developed in an experiment, which is aiming at the development of soil degradation indices from ground spectroradiometry and finally to apply these to soil degradation mapping with hyperspectral image data. To this end airborne MIVIS imaging spectrometer data of the Fortore Beneventano test site in Southern Italy were analysed in cooperation with the CNR Irrigation Institute (CNR - ISPAIM, Ercolano). After radiometric rectification of the image data and the collection of a field/ laboratory spectral library, linear spectral mixture modelling was used to decompose image spectra into fractions of spectrally distinct mixing components. The objective of this approach is of course to isolate the spectral contributions of important surface materials ("endmember abundance") before these are edited and recombined to produce thematic maps. Here the resulting abundance estimates (fractions) were evaluated to identify and map soil conditions as well as to obtain an improved measure of dry and green vegetation cover, which are considered important parameters for monitoring soil erosion processes. In the given example, a comparison between image derived values of clay and carbonate fractions and those obtained in the pedological field and laboratory analyses showed, that the differences of percent carbonate and clay abundance fall in the same range of soil mineralogical/chemical variation as observed between degraded and not degraded samples of Calcaric Regosols of the Fortore. Against this background, a soil degradation index based upon the ratio of carbonate to clay abundance was defined, according to the increasing values of percent calcite contents versus decreasing clay fractions and their relationship to the degree of degradation of the available soil samples. An example of the resulting, spectral endmember based classification and mapping is given in Figure 3.2.

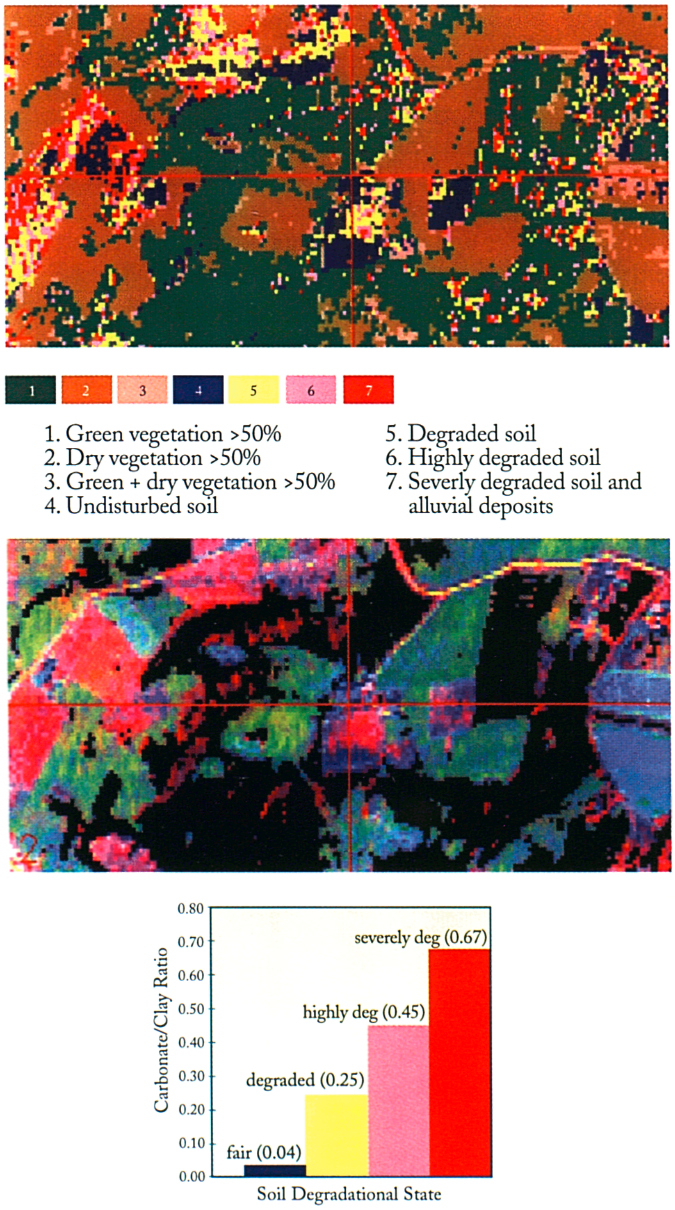


Figure 3.2 : Example of vegetation cover and soil degradation mapping with MIVIS data.

In the context of the **SPOT VEGETATION (VGT) Preparatory Programme**, EMAP is investigating the function the system can fulfill in an operational setup for monitoring land degradation in the Mediterranean basin. The objectives in the pre-launch phase comprise the synthesis of VGT type data from TM data over areas typical of our study sites. The technique applied to generating the VGT spectral characteristics includes the following steps:

- generate a fraction image for the underlying TM image using linear spectral mixture analysis, preferably using multiple endmember sets to better describe the spectral variability of the scene. Fine resolution endmember spectra are obtained from field or laboratory measurements and convoluted with TM bands.
- reconstitute the image in VGT spectral bands from the fraction image and from the endmember spectra after convoluting those with VGT bands.
- The final VGT image is obtained from the result by spatial averaging.

This approach may be validated either by generating both TM and VGT simulated imagery from hyperspectral images with suitable spectral coverage, by spectral and spatial integration, or by evaluating the method while using it for the reconstruction of one TM band from the others, thus quantifying its potential accuracy for spectral extrapolation as well as the information contents of any single band as function of the observed target. On first trials, the latter approach showed satisfactory results for extrapolating the 450-520 nm band of TM from the others, although a single endmember set was used and the selection of those endmembers was not optimised in any way.

Perspectives for 1997

In 1997 the SPOT VEGETATION, DeMon and MEDALUS SCA projects will be continued and CAMELEO is expected to be implemented with support of the DG XII INCO/DC programme. Furthermore, the imaging spectrometry activities will be continued and extended by a new airborne imaging spectrometry campaign using the DAIS (Digital Airborne Imaging Spectrometer) of DLR (German aerospace research institution). DAIS is planned to be flown over the DeMon La Peyne test site in S-France, in the framework of the Large Scale Facility activity under the DG XII TMR programme (Training and Mobility of Researchers).

The overall principal objective of both competitive and institutional work is to set-up and demonstrate an integrated concept for an operational Earth observation system to operationally monitor desertification processes at regional scale in the whole Mediterranean basin (North and South), in order to contribute to the fulfilment of the UN Convention to Combat Desertification (CCD) and to support sustainable land management to mitigate desertification.

The general concept is to integrate all available data on the studied environments. This will include data collected on the ground as well as data acquired by Earth Observation programmes. The scientific approach relies heavily on the experience and results already gained by the different projects and international initiatives such as the ROSELT-OSS network. This includes the identification of ground indicators of local ecological changes (degraded condition, stable, restored..), the determination of those that can be remotely sensed, the selection of the most adequate high resolution satellite data, refinement and design of processing algorithms and data output.

In the next step, this bottom-up approach is then to be applied to historical records of data to identify long term changes. These local changes shall be analysed in a regional eco-climatic context using medium resolution imagery acquired from NOAA-AVHRR. Combining these results with socio-economic data is envisaged to allow the recognition of changes in relation to land use. Future scenarios shall be derived from experiments on modelling changes.

Consequently the 1997 technical work programme will concentrate on the following aspects:

- Retrospective evaluation of high resolution remote sensing data (Landsat MSS, TM, SPOT) towards the development of land degradation and desertification in the past 20 years on our project reference sites.
- Characterisation of the sites in terms of degradational state, trends and desertification risk by means of remote sensing and GIS
- Definition and demonstration of a standardised processing chain for the production, evaluation and up-grading of a regional map of desertification risk

3.2

Landslide mapping and monitoring in mediterranean landscapes

Summary of Objectives

- Evaluation and development of advanced image processing methods for landslide detection mapping and monitoring in Mediterranean regions

1996 Milestones

Febrary: Presentation of results at the ERIM Geological Remote Sensing Conference, Las Vegas, USA

September: Presentation of results at the ILRG International Conference on Landslides, Granada, Spain

1996 PROGRAMME OF WORK

Introduction

Landslides represent a major hazard in Mediterranean Europe mainly as a consequence of the particular rainfall regime and seismic activity of this region. Mapping the occurrence and monitoring the activity of landslides are essential steps towards an adequate land planning and management in mass movement prone areas.
In this context, the development of semi-automatic processing techniques on remotely sensed data is being pursued as a means for producing cost-effective, up-to-date landslide hazard information.

Methodological Research

During 1996 specific methods have been developed and applied to high spatial resolution airborne optical data to discriminate major landslide features, with the assistance of Brunel University, UK. Supervised texture classification techniques proved to be very useful in discriminating hummocky slope surfaces in sedimentary formations caused mainly by earth flows and single and multiple rotational slides. For this task, daytime thermal-IR imagery was particularly useful in low vegetated areas because of its sensitivity to slope surface morphology.
Colour enhancement and discrimination techniques applied to multi-channel optical data were shown to be of great potential to identify landslide scars as well as other signs of slope instability, such as rock masses and debris detached or slipped from rocky massifs due to complex mass movements.

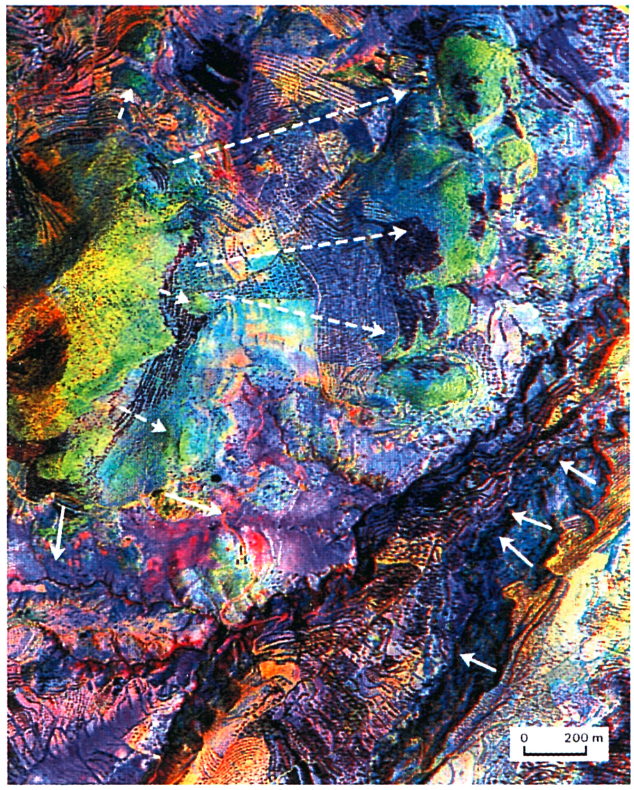


Figure 3.4 : Statistically selected, decorrelation-stretched ATM band triplet of Los Veléz district. In the upper half of the image, Jurassic limestone mounts and masses (greenish hue) embedded in Miocene clay (magenta-cyan hue) correspond to relict and reactivated complex slides. Single rotational slides in Miocene clay are shown in the right low corner. Solid arrows indicate active or recent movement; dashed arrows indicate inactive landslides.

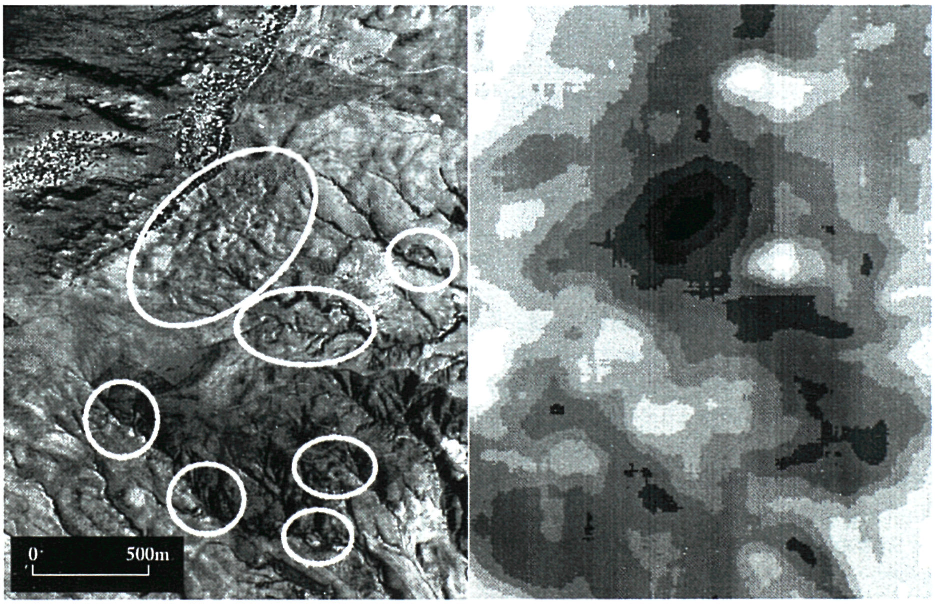


Figure 3.3 : Left: Normalised ATM thermal-IR image of Los Veléz district, Spain. Landslides are circled. Right: Texture spectrum segmented image. Darkest tones generally correlate with unstable slopes (ATM data supplied by INTA).

Perspectives for 1997

Major efforts will be put on further validating and tuning the landslide identification methodology on high spatial resolution spaceborne imagery. DEM will be used to help increasing the performance of these methods. Monitoring landslide activity from time series analysis of these data is expected to start during the last term.
According to the resources available in 1997 work could extend to other European regions highly prone to slope instability.

3.3

Firs Project - Forest Information from Remote Sensing

Summary of Objectives

- To contribute to the development of a unified European forest information system.
- To develop methods for providing both sectorial (i.e. production-related) and environmental (i.e. ecology-related) forest information, in the form of both statistical and mapped data.
- To use remotely sensed data as a major source of information.
- To use geographical information system (GIS) techniques to reduce the cost of data collection, data handling and data distribution.

1996 Milestones

January: Completion of study contract on nomenclature for mapping European forests by remote sensing.

June: Validation of regionalized forest map of Europe (Foundation Action 1).

July: Release by DGVI of ITT study "the application of remote sensing to changes in forest lands" defined in collaboration with the FIRS project.

Validation of AVHRR-derived forest map of Europe.

September: Kick-off meeting for Share-Cost-Action Project MARIE-F.

October: FIRS International Workshop: "Application of Remote Sensing in European Forest Monitoring", University of Agriculture, Vienna, Austria.

December: Kick-off of FIRS/CEO's Application Project on Forestry.

1996 PROGRAMME OF WORK

Introduction

The project comprises two main parts. The first part consists of three Foundation Actions: 1) Regionalization and stratification of European forest ecosystems; 2) Design of a system of nomenclature for European forest mapping and 3) Compilation of a European geo-referenced forest data directory. The second part is divided into six Themes listed in Table 3.2.

A significant part of the work in 1996 focused on completing the work on Foundation Action 2 and on producing the first experimental AVHRR-derived forest / non-forest map of Europe. This work supports activities in Themes 3 and 4 of the FIRS Project, and activities in support to the EFICS (European Forestry Information and Communication System) Programme, established by DGVI to fulfil the need to define and co-ordinate forest policies among the EU Member States, and the UN-ECE/FAO Global Forest Resource Assessment for the year 2000.

New activities have been launched in 1996 in collaboration with DGVI, the CEO Project and as a Share Cost Action awarded by DGXII.

Foundation Action 2: Design of a System of nomenclature for European forest mapping.

This study was completed in January 1996. The compilation of information needs showed that many attributes and information requests are similar throughout Europe. The assessment and comparison of national systems of nomenclature revealed considerable differences and inconsistencies. For some attributes, only minor efforts would be required to come up with harmonised results at the national level, whilst considerable effort would be required to reach a minimum level of harmonisation for the information most requested. As a consequence, the implementation of a unique, standardised system of nomenclature (although desirable), is not a realistic solution to the problem, due, not least, to the vast increase in resources required by single countries to put such a system into practice.

On the other hand, the precision of information compiled at the international level could be improved, if well devised statistical methods are applied for the data compilation

Theme	Objective
1. Forest statistics	To develop methods to perform effective inventories and to provide statistics on sectorial forest information.
2. Afforestation monitoring	To describe the regional variation and to monitor the set-aside afforested lands.
3. Forest mapping	To develop standardised and operational methods for mapping the forests of Europe at scales of 1:1,000,000 and 1:100,000.
4. Forest monitoring	To develop methods and models for mapping and monitoring the dynamics of forested areas.
5. Forest modelling	To develop models to study and monitor changes in forest ecosystem structure and dynamics, and to identify those ecosystems under stress.
6. Mapping and monitoring of grassland and non forest natural vegetation	To develop methods for operational mapping and monitoring of ecosystems consisting mainly of grassland and natural vegetation inclusive of coastal ecosystems.

Table 3.2 : The Themes and their main objectives.

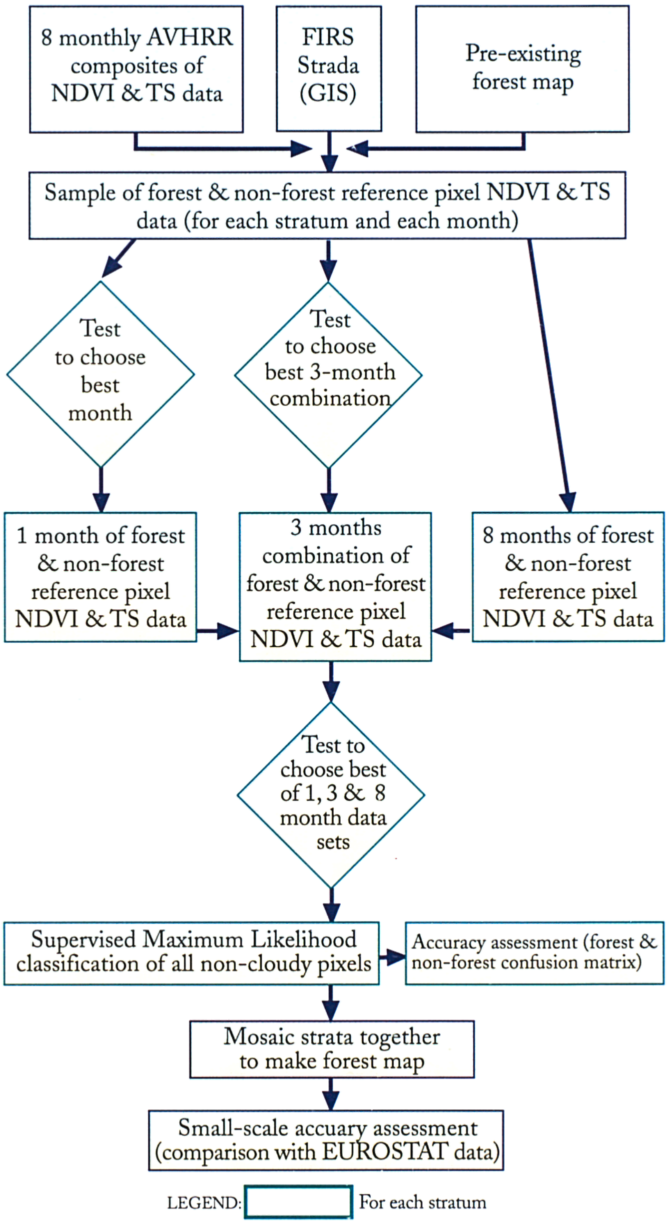


Figure 3.5 : Classification methodology for AVHRR-derived forest map of Europe.

and analysis. One recommendation could be to apply a multi-phase sampling design for stratification, where, one or more phases could be accomplished by remote sensing.

Units or strata could be assessed using satellite data, for example, for forest area, which could then be used as a weight for the attributes used in the analysis procedures.

Theme 3: European Forest Mapping

A methodology for mapping the forests of Europe at a maximum scale of 1:1 million using low spatial resolution AVHRR data has been developed. It is intended to be operational and will provide a mechanism for a unified European forest inventory that may be repeated on a regular basis.

The classification methodology is shown in Figure 3.5. In an attempt to reduce sensitivity to external variations (e.g. cloud cover and climatic effects) and to intrinsic surface variations (e.g. vegetation remotely sensed response varies with maturity, canopy closure, moisture status) the classification is performed in a stratified manner. The classified strata are mosaiced together to produce a European forest/non-forest map. A small-scale accuracy assessment is performed by comparison of the map results with existing EUROSTAT forest statistics (Figure 3.6).

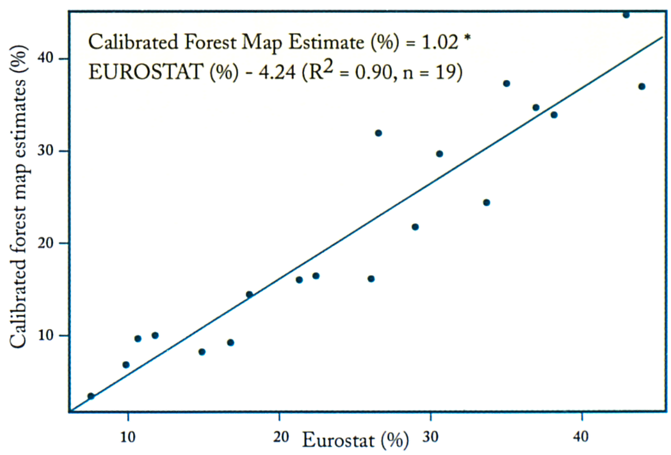


Figure 3.6 : Percentage forest cover estimates from the AVHRR-derived map and EUROSTAT statistics for France. Each point represents the forest cover estimates for NUTS-2 level regions.

The performance of the AVHRR-derived forest/non-forest map of Europe has been tested using classified Landsat TM images. Even though the available TM scenes were not optimal in terms of location and percentage forest cover, the findings illustrate the limitations of AVHRR data for mapping purposes. Using a threshold of 50% forest cover in a classified TM pixel as *"forest"*, the average (using 33 TM scenes) accuracy of the AVHRR-derived map (as calculated using a confusion matrix) was found to be 82%. The results varied from 64% to 99%.

Once the forest cover threshold in the Landsat TM was changed in order to identify the cover fraction in the TM data which corresponded with the highest number of correctly classified AVHRR forest pixels two interesting findings were revealed. Firstly, the "optimum forest cover threshold" varied (between 10% and 90%) from site to site (Figure 3.7). This indicates the difficulty of defining forest as derived from coarse spatial resolution remote sensing data, and the strong influence of small forest parcels distributed randomly within a single AVHRR pixel. Secondly, the average of the optimum correspondence between TM and AVHRR forest pixels was found to occur at 62% forest cover in the TM data. This confirms the rather significant under-estimate of forest cover inherent to the interpretation of AVHRR data.

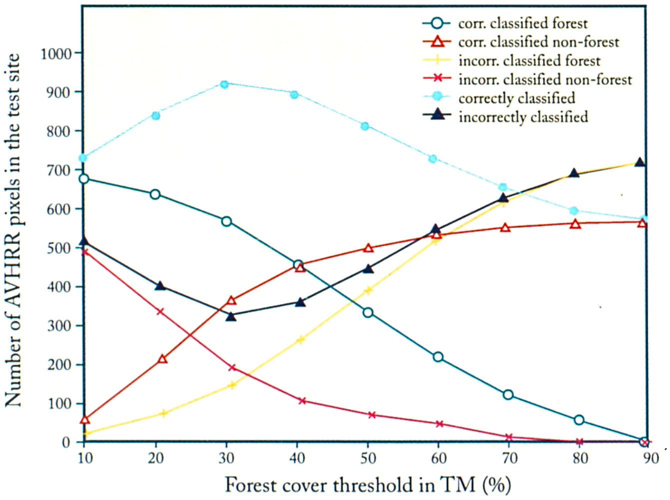


Figure 3.7 : AVHRR classification results for one test site as a function of forest cover thresholds used in the classified Landsat TM image.

Conferences and Workshops

In October 1996 the FIRS Project, in collaboration with the Agricultural University in Vienna, the Joanneum Research Centre, Graz, DGVI and EUROSTAT, IUFRO (International Organization of Forest Research Organizations) and EFI (European Forest Institute) organized an International Workshop on the *"Application of remote Sensing in European Forest Monitoring"* attended by over 100 people from 19 countries in Europe, Canada and the USA. Three main topics were considered: Multi-source data integration and GIS; Regional Studies, stratification and sampling, and Change detection and monitoring of forest condition. Keynote speakers presented the current status and future potential of remote sensing in National, European and Global Forest Resource Assessments. The papers and recommendation will be published in 1997.

New activities

Collaboration with DGVI

This takes the form of assisting DGVI FII.2 with the scientific and technical expertize to prepare and monitor a study contract on *"The application of remote sensing to changes in forest lands"*. The FIRS Project assisted in the preparation of the ITT, and will continue to provide expert advise as a member of the study's Steering Committee. The study will be carried out by GAF mbH, Germany, and will run for 18months. The kick off meeting will be in February 1997.

Collaboration with the CEO: FMERS Project

FMERS (Forest Monitoring in Europe by Remote Sensing) is funded by CEO and technically carried out by EMAP where the technical and scientific expertise is provided by FIRS. The study started in December 1996 and will continue for 18 months. It represents an initiative to build on the work of the FIRS Project in the utilization of remote sensing data to address some topical attributes for monitoring forests at a European scale. These are:

- forest area and other wooded land
- forest composition (tree species)
- forest biomass estimation

Shared Cost Action: MARIE-F Project

The FIRS Project is one of five partners of this project co-ordinated by EARS bv. (Environmental Analysis and Remote Sensing), in The Netherlands. The objective is to develop satellite-based methods and models to estimate and monitor forest timber resources and forest vitality in Europe. The work will be based in four main test sites in Europe;- 1) the Black Forest (Germany), 2) Lozere (France), 3) Veluwe (The Netherlands) and 4) Porvoo (Finland). A user evaluation survey will be carried out to assess the utility of the results for forest inventories, forest industry and forest planning and management. The project will run for 30 months as from September 1996.

Perspectives for 1997

Apply and test the results of FIRS Foundation Actions 1 and 2 for mapping and characterizing the forests of Europe. Build on Theme 3 (European mapping) to raise the methodology to an operational system.

Advise and closely monitor the DGVI study on "The application of remote sensing to changes in forest lands".
Carry out CEO's Application Project on Forestry.
Commence work on the Share Cost Action - Marie-F.
Continue to assist in the development of international forest programmes, in particular with EFICS and the UN-ECE\FAO Global Forest Resource Assessment.
Host a workshop in March 1997 on "Assessing the information quality of maps versus sampling for studying land cover at regional scales".
Host a European Workshop as part of our support to planning of the FAO/ECE's Global Forest Resources Assessment - 2000.

3.4

Mapping European Land Cover with NOAA-AVHRR Data

Summary of objectives:

- To develop a robust methodology and processing chain for the production of a European-wide land cover classification.
- To produce a digital European land cover data set with a spatial resolution of 1 km x 1 km.
- To assess the accuracy of this database by using existing land-cover statistics.

1996 Milestones

July: Land Cover Map for Western Europe produced.

Introduction

The study on mapping European land cover with AVHRR data constitutes a part of the ongoing activities at the SAI which aim at supporting the efforts of the Commission Services to provide a tool for monitoring European land cover changes.

For this purpose the data in the MARS-AVHRR data archive were selected as input to a demonstration project with the aim of developing a reliable methodology based on the use of low spatial resolution satellite data. It was a-priori accepted that the resulting nomenclature would consist of only a small number of classes, and that the classes may not fully match the second level in the hierarchy of the CEC-CORINE Land Cover nomenclature.

1996 PROGRAMME OF WORK

Sixty-eight relatively cloud-free geometrically and radiometrically AVHRR mosaics of Europe were selected. The study region covers the geographical area from the Portuguese coast to central Crete and from northern Algeria to southern Sweden. The AVHRR data were acquired over the main growing season from March to October 1993. The selected mosaics were composited independently into eight monthly maximum value composites of the NDVI (Normalised Difference Vegetation Index) (MaN) and Ts (surface temperature) (MaT) data.

The MaN and MaT data were processed independently on a regional basis in an attempt to reduce topographic or climate induced variations in NDVI and Ts. For this reason the study area was stratified into 13 ecosystem regions and classified independently on a regional basis. The ecosystem regions were defined following the results of FIRS Foundation Action 1 i.e. the regionalization and stratification of European Forest Ecosystems. Thereafter a PCA was performed within each ecosystem region. The first two PC's, which in the present case best described the data and which appeared to contain the highest proportion of variance, were chosen for input into an unsupervised clustering program in lieu of the original data.

Class labelling was performed using ten pre-classified high spatial resolution satellite images selected from the MARS archives. Each image of the MARS high resolution test sites has a pixel dimension of 20m by 20m and is composed of 2000 by 2000 pixels covering 1600km≤. The AVHRR clusters that fell within a selected MARS test site were resampled to the same co-ordinate system and pixel resolution as the pre-classified high spatial resolution MARS test imagery. The MARS classes were then compared with the yet unassigned resampled AVHRR clusters. At least two, but up to four MARS test images within each ecosystem region were treated independently in this manner and the results compared to ensure consistency within cluster labelling within a single region. The determined cluster labels were applied to the remaining AVHRR data in that ecosystem region. Urban classes were located across the entire image using a vector based database (DCW). The *"populated place"* layer of the DCW depicts the urbanised areas that can be represented as polygons at a scale of 1:1 million.

Six classes (plus missing/unassigned data) within the AVHRR data were discriminated. These are 1) built up areas; 2) sparsely vegetated land; 3) forest; 4) Grassland; 5) Cropland; 6) Water and 7) Missing/Unassigned data. These classes were then compared with land cover summary statistics as collected by EUROSTAT.

Strong spatial correspondence between the cluster patterns representing built-up areas and the urban areas (as defined in the DCW database) was generally observed across Europe, and led to some confidence in the assignment of the urban class labels. However, for surfaces covered with vegetation and especially those with natural vegetation, class assignment was more complex. A strong relationship between the AVHRR derived cropland and forest classes at the EUROSTAT NUTS-2 land cover statistics (1993) was observed. Due to the lack of available data for Belgium, France, Germany and Holland and high percentage cloud cover in the data , it was possible to compare the surface area coverage of cropland in only twenty seven NUTS-2 areas. (Figure 3.8).

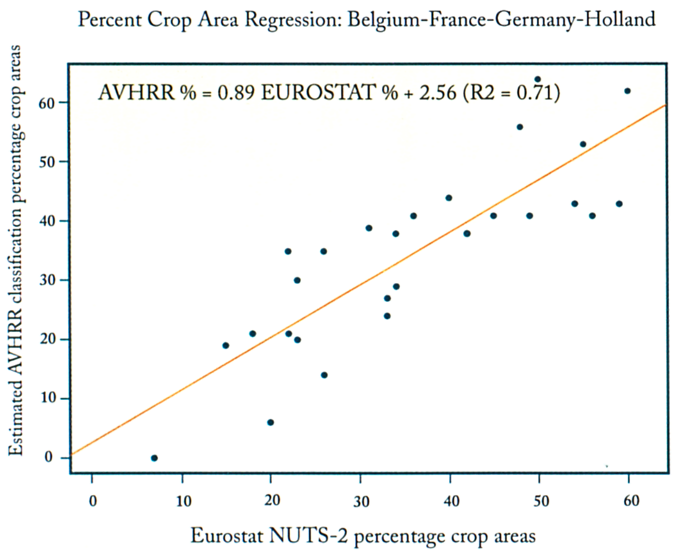


Figure 3.8 : Graph showing the R2 correlation between the surface area coverage of cropland as derived from the AVHRR data and EUROSTAT for 27 NUTS-2 level regions in Belgium, France, Germany and The Netherlands.

These results represent the final output from the project, which has now been discontinued as an activity in EMAP.

3.5

PHARE MERA Project, Forestry component, Support to DG I

Summary of objectives

Assist in preparation and implementation of forest ecosystems and land degradation mapping and monitoring by remote sensing, in six Central and Eastern European contries - i.e. Bulgaria, Czech Republic, Hungary, Poland, Romania and Slovakia.

1996 Milestones

- Completion of the PHARE MERA '92 sub-projects on Forest Ecosystems Mapping and Land Degradation Mapping in five participating countries.
- Organisation of the Technical Workshop *"Environmental Mapping and Monitoring using Satellite Remote Sensing and GIS"*, held in Warsaw (28/29 November 1996).
- Participation in the three-member winning consortium, in response to the Call for Tender for the Preparation of a PHARE Multi-Country Forestry Programme.

1996 PROGRAMME OF WORK

The PHARE MERA (MARS and Environmental Related Activities) '92 sub-projects on Forest Ecosystems Mapping and Land Degradation Mapping, which were co-ordinated by EMAP, were completed in five countries (Czech Republic, Hungary, Poland, Romania, and Slovakia).
For each sub-project, two types of results were produced:

1 On a country level, digital geographic databases containing thematic layers of major environmental-related variables, including forest regions and strata, forest types (e.g. species, timber volume, age, health), land cover, potential and actual land degradation risk, soil maps, digital elevation models. Figure 3.9 shows the results of the MERA '92 forest regionalization of Hungary into six forest regions and 19 forest strata, defined according to the variables stand type, stand volume, stand height, and forest health.

2 For representative test areas, digital geographic databases of detailed ground reference data and classified forest and land degradation types.

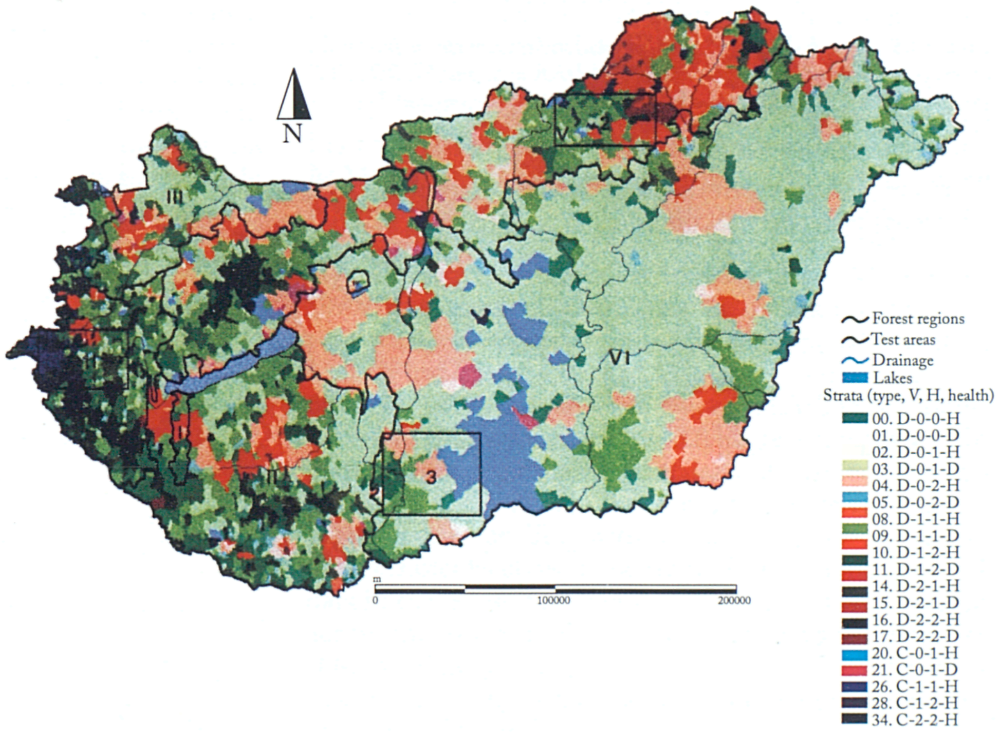


Figure 3.9 : Regions and strata of the Hungarian forest ecosystem.

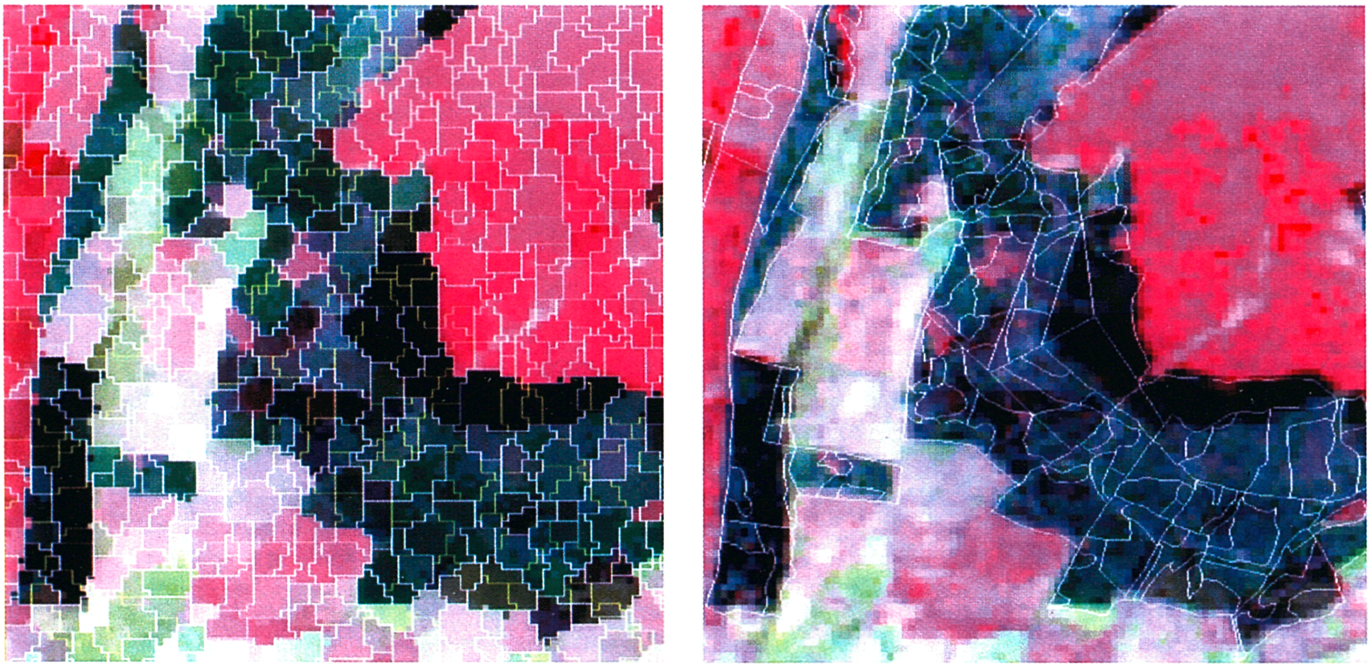


Figure 3.10 : Use of SILVICS for automatic forest stand delineation. On the left, conventional ground-based forest stand boundaries are overlaid on a 3x3 km Landsat TM image of central Ireland. On the right, the boundaries derived automatically by SILVICS's segmentation method are overlaid on a smoothed version of the image.

The results of both sub-projects were presented at an international workshop, organized and co-ordinated by EMAP, in Warsaw on 28-29 November 1996 and at the MERA Project Results Conference, in Bratislava (10-11 December 1996).

EMAP's software for parcel-based forest classification (SILVICS) was installed and demonstrated in MERA agencies in Hungary, Poland, and Romania. Figure 3.10 illustrates the use of SILVICS for automatic forest stand delineation.

A satellite-based methodology for monitoring forest diversity has been developed at EMAP. The methodology is based on the assessment of the three main components of forest diversity: composition, structure, and development. The methodology is illustrated in the case of a national forest park in Figure 3.11.

EMAP, together with two other international partners, formed a consortium which won the contract for the Preparation of a PHARE Multi-Country Forestry Programme.

Perspectives for 1997

- Technical co-ordination of the PHARE MERA `95 activity on Forest Ecosystems Mapping in Albania, Estonia, Latvia, Lithuania, Slovenia.
- Preparation of the Terms of Reference of projects for the PHARE Multi-Country Forestry Programme, which will start in 1998.

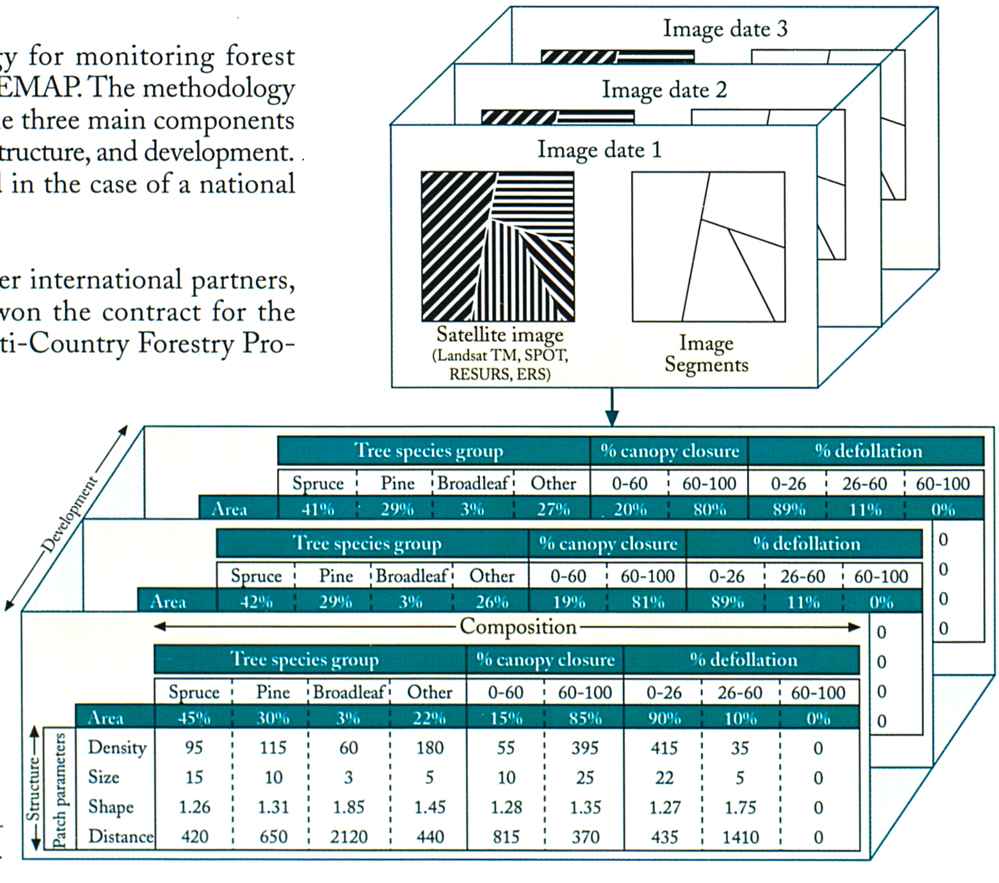


Figure 3.11 : Satellite-based methodology for monitoring forest diversity.

3.6

Advanced methods

Summary of objectives

Develop techniques for exploiting complex remotely-sensed imagery for environmental mapping and monitoring purposes and perform a technology watch concerned with new approaches. Specific areas include:

- multisource data fusion and data sets of high dimensionality
- advanced visualization methods and operational methods for map generalization
- integration of fuzzy and neural classifiers, texture and contextual classification methods
- development of a long term European GIS research strategy with relevance to remote sensing

1996 Milestones

March: Beginning of COMPARES Concerted Action on neural network applications in remote sensing

May: Siemens SYNAPSE-1 parallel neural network computer installed in Ispra

October: Research strategy workshop held in Cagliari as part of the COMPARES Concerted Action

November: Expert group meeting organized at Ispra on the development of a long term GIS research strategy for Europe

Commencement of FLIERS shared cost action project on fuzzy land use analysis

1996 PROGRAMME OF WORK

Introduction

The work related to *"advanced methods"* is principally concerned with research and development on the automatic interpretation of imagery gathered from Earth observation satellites and on the integration of remote sensing data into Geographical Information Systems (GIS). During 1996 these activities expanded considerably and a number of new projects and activities started -partly as a result of success in winning shared cost action projects within the scope of the Fourth Framework programme and also two competitive projects in support of the Commission. These new activities, plus the continuation of institutional research underway since 1995, are described below.

Concerted Action *"COMPARES"*

The Concerted Action *"COMPARES"* is funded within the Environment and Climate Programme of the European Commission. The primary objectives of the activity are to draw up an agenda for future research based on an assessment of what has been done so far, throughout the European Union and elsewhere, on the application of neural computing in remote sensing and on an evaluation of the potential benefits to be derived from pursuing further research and development in this theme in a coordinated manner.

To meet the above objectives two workshops were organised within the scope of COMPARES:

- an open European workshop on connectionist computingin remote sensing , held at the University of York, England, in July 1996. The aim of this workshop was primarily to explore the current state on connectionist computing in remote sensing.
- a restricted research strategy meeting, held in Cagliari, Sardenia in October 1996. The aim of this meeting was to identify priorities for future research as input to deliberations on future funding within European programmes.

The proceedings of the workshop held at York and the report with the recommendations for future research from the meeting held in Cagliari will be published in 1997.

Project *"FLIERS"*

This project, started in November 1996, is funded by the Environment and Climate Programme of the European Union for a period of three years. The primary objective of the project is to provide a conceptual improvement over current approaches to land cover mapping resulting in improved accuracy and use of Earth Observation data. The approach involves three complementary activities:

1 neuro-fuzzy classifiers: This will involve use of neural network classifiers based on fuzzy theory, texture-based neural computing, mixture modelling and other alternative classifiers. All outcomes will be compared with standard classifiers.

2 scientific visualisation: This will involve exploratory projection pursuit to assist in multi-dimensional feature reduction, feature selection for classification, and multi-dimensional feature visualisation based on virtual reality technology.

3 ground verification: The approach to field mapping will require the development of novel approaches to mapping the continua of vegetation so that it can be used to verify mixed classes mapping with multiple resolution remotely sensed data.

The research partnership, the Universities of Southampton and Leicester in the UK, VTT Automation in Finland, the University of Thessaloniki in Greece and the EMAP unit of SAI/JRC. EMAP is mainly responsible (with support from the University of Leicester) for the activity on scientific visualisation and will actively participate in the activity on neural and fuzzy classifiers.

Benchmarking of neural network parallel hardware systems for remote sensing

The aim of this project is to benchmark the performance of the European neurocomputer SYNAPSE-1, developed by Siemens-Nixdorf Advanced Technologies, in an application domain such as remote sensing which could benefit from the use of high performance neural networks.

Remote sensing image datasets are very large and in the near future, with the advent of a new generation of hyper-spectral satellite sensors, will contain very high dimensional data. In addition to the size and dimensionality of the data, image classifications often need to combine satellite imagery acquired by different types of sensor and at different dates.

Certain attributes of artificial neural networks make them amenable to parallel-processing implementations that could efficiently carry out the kinds of multi-temporal analyses, multi-sensor data-fusion and thematic classification of satellite data increasingly required by the remote sensing user community.

In the SYNAPSE-1 neurocomputer the power of its high-performance parallel processors is used to deal with one of the major stumbling-blocks when using neural network techniques - their extended training times. During network training several thousands of exemplar image-pixels (whose classification is known a priori) are presented to the network. After each complete presentation of the set of exemplar pixels, called an epoch of training, the network adapts its pattern of connectivity. This cycle of presentation and adaptation is a highly iterative gradient descent to find a good mapping from input image pixels to land-cover/land-use class. The training process typically requires several thousands of epochs and it is by calculating the network connectivity changes for each epoch in parallel, that the SYNAPSE-1 alleviates the problem of extended network training times.

Candidate remote sensing applications have been identified for study: like classification, geometric and atmospheric correction. The benchmarking criteria which will be used to evaluate results have also been specified: CPU time for each epoch of training, training elapsed time, number of network connections updated per second of training and the number of satellite images that can processed per hour.

The first few months of 1997 will see the initial benchmarking trials of SYNAPSE-1 carried out with remote sensing data. The project should be completed in the spring of 1997 with a workshop/training course for researchers interested in exploiting the neurocomputing potential of SYNAPSE-1 in remote sensing or similar application domains.

Use of neural networks for improving satellite image processing techniques for land use classification

This activity was undertaken in support of the Statistical Office of the European Commission (EUROSTAT) following a successful bid to an open call for tender for Commission support activities.

The general objectives of this project are to describe, demonstrate and test the potential of artificial neural networks (ANNs) for land cover/land use classification of satellite data, according to the hierarchical nomenclature *"Classification for Land Uses STatistics of Eurostat's programme on Remote sensing and Statistics (CLUSTERS)"* of land use classes (see Table 3.3). Moreover, the work also involves: analysis of the potential of automating image classification for land use using ANNs in terms of level of detail, the possible use of ANNs in quality control procedures during the process of classification/interpretation, and the quality control of the results.

The project has been a joint collaboration between the Space Application Institute (SAI) and the Neural Networks Laboratory of the Institute for Systems, Informatics and Safety (ISIS).

Level I		Level II		Level III		Level IV	
A	Man made areas	A1	Residential areas and public services	A11	Residential areas	A111	Continuous and dense Residential
						A112	Continuous medium density Residential
						A113	Suburban Residential areas
						A114	Discontinuous Residential areas
						A115	Collective Residential areas
				A12	Public services, local authorities	A120	Public services, local authorities
		A2	Industrial or comercial activities	A20	Industrial or comercial activities	A201	Heavy industry
						A202	Manufacturing industrial activities
						A203	Comercial and financial activities and services
						A204	Agricultural holdings

Table 3.3 : Clusters scheme - Man Made Areas.

The main test area used for this project has been the city of Lisbon, Portugal and satellite images covering the area around the city were acquired. The working scale of the remotely sensed multitemporal satellite data is 1:25000, and the research and development work focuses both on urban areas and global land use. Two Landsat Thematic-Mapper images taken in January and June 1991 and one Synthetic Aperture Radar image taken in March 1992 have been used in the project.

The work has so far concentrated on image and ground dataset preparation according to the CLUSTERS nomenclature, on developing the methodological approach, and on the first experimental results of land cover/land use classification. The final results will be available in April 1997.

Development of a European GIS research strategy

The GIS support activity for DGIII-F in 1996 was shared between ISIS and SAI institutes.

The support activities are oriented toward the provision of scientific and technical support for the execution of the Information and Communications Technologies (ICT) Specific Research Programme, and should help to provide:

- technology transfer to industry, the scientific community and within the Commission
- support to the existing and planned Research and Technical Development work in collaboration with industry and
- assistance to DGIII in preparatory and prenormative work towards managing information flow from ICT research projects to standardisation bodies and vice versa.

The milestones achieved by SAI on this project for 1996 include the following:

Dissemination of Information Activities

- the development of a WWW server displaying information regarding GIS information projects sponsored by the European Commission and containing GIS links and identifying project logo. Address: http://thalassa. jrc.it/dg3gis/dg3gis.htm.
- inital preparatory work to produce a Project Summaries Book containing all the GIS projects that are on the WWW server.
- establish plan for concertation mechanisms activity.
- the hosting of a GIS Expert Panel meeting (19/20th November) held at the JRC, Ispra, to assess the future needs for GIS Research and Technology within Europe. The participants included some of the most respected authorities in the field of GIS and significant leaders from Industry. The Panel's report will soon be published. It contains strategic recommendations into the future of GIS Research and Development within Europe.

SIR-C/X-SAR Data Processing

During the last three days of the second SIR-C/X-SAR shuttle mission in October 1994 data was acquired especially for interferometric purposes. The activity, carried out together with the German Aerospace Research Establishment (DLR), aimed at assessing the usefulness of the imagery provided by the SIR-C/X-SAR mission and the subsequent interferometric processing, for classification purposes.

The interferometric processing included the generation of coherence maps as well as the derivation of a digital elevation model in order to allow a precise geocoding of the data, which is essential for multi-sensoral investigations and to enable the derivation of calibrated coherence maps. Following the interferometric processing the three derived coherence maps together with seven detected images were used for classification purposes. For the classification a fully connected multilayer feed forward neural network was used. A number of experiments were performed including :

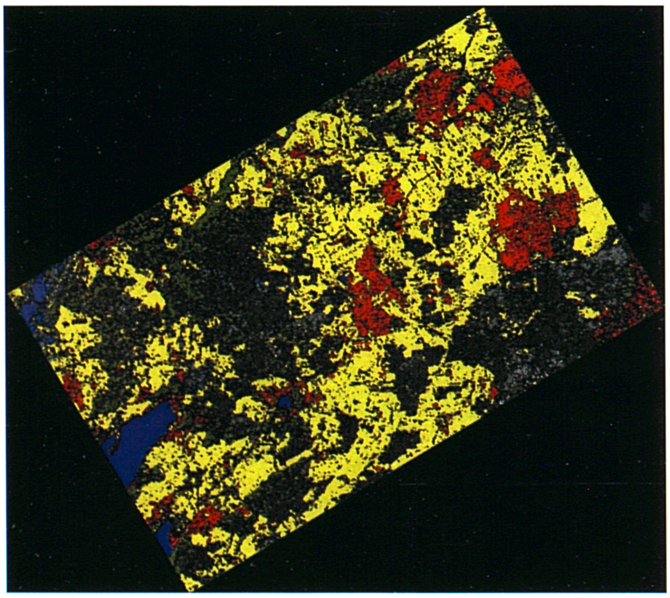
- classification of single frequency imagery using amplitude and coherence information.
- classification of all detected imagery and all coherence information.

Following the interpretation of the results it was obvious that the coherence maps in all cases added a wealth of information; a number of classes, especially urban and forest areas, were discriminated with very high accuracy only by adding the coherence data.

Ground Classes	% Producer´s Accuracy			
	Neural Network		Max. Likelihood	
	SIR-C	TM	SIR-C	TM
Settlements*	75.25	94.24	77.29	85.42
Agriculture	88.14	99.52	85.28	99.59
Deciduous Forest	50.20	76.28	58.10	75.10
Coniferous Forest	81.19	95.05	69.97	97.03
Clear Cuts	73.53	86.47	75.29	85.88
Lakes	97.64	99.06	96.70	96.70
Wetlands	88.28	87.93	79.66	21.38
Overall % Accuracy	82.05	94.68	79.21	87.96

*Table 3.4 : Classification accuracies with SIR-C and TM data. * The "Producer's" accuracy for settlements appears to be better for TM, but for the mapping (positional) accuracy, the reverse is true.*

For comparison purposes a Landsat TM image co-registered to the SIR-C/X-SAR data, was classified using the same reference data sets. The comparison between the TM classification and the entire SIR-C/X-SAR data set (multi-frequency and coherence maps) showed that urban areas are discriminated more accurately by the SAR data set while TM data seems to classify more accurately most of the other classes (see Table 3.4 and Fig. 3.12). It has to be noted however that the SAR data sets were not filtered prior to the classification and the results were affected by speckle noise.



Testsite Oberpfaffenhofen
Neural Network Classification of Multi-temporal C, L and X band SAR data using amplitude and phase information

background	Coniferous forest
Settlements	Clear cuts
Agriculture	Lakes
Decidous forest	Wetlands

Figure 3.12 : Neural network classification with SIR-C/X-SAR data over Oberpfaffenhofen test site.

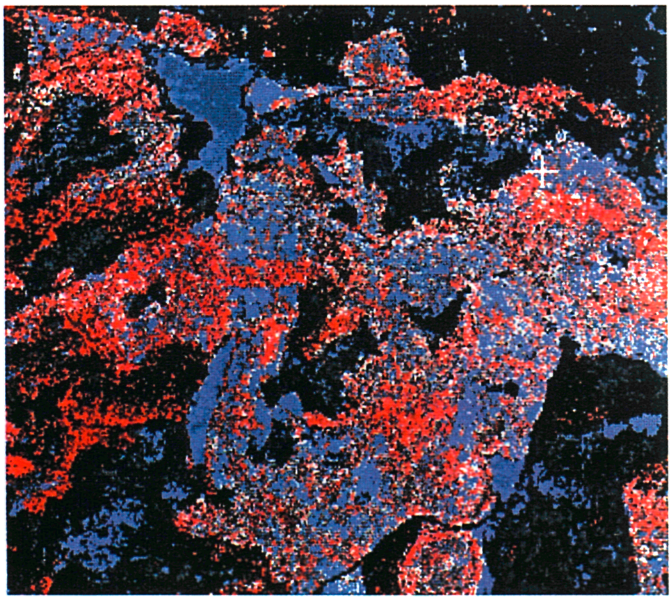


Figure 3.13 : Fuzzy neural classification of a mixed forest area of SW Scotland using TM data. The image shows percentage forest species. Pure red = 100% sitka spruce; Pure turquoise = 100% lodgepole pine; black indicates that neither are present; intermediate shades represent varying percentage composition.

Neural network classification of mixed land cover pixels
This activity is a continuation of institutional research work from 1995. Work carried out this year focussed on a quantitative assessment of the capabilities of neural networks for identifying components of mixed pixels - where a mixed pixel is defined as a pixel in an image whose coverage, according to ground truth, is not 100% of one homogeneous land cover class only.

Preliminary work revealed that qualitatively, neural network output strengths which have been shown mathematically in the literature to approximate Bayesian a-posteriori probabilities, were indeed related to mixture classes. Quantitatively, it was found that for a two class mixture, the dominant class could be identified with an accuracy of ~85% and the second with an accuracy of ~60%. Future work wil involve the comparison of results with other techniques in particular maximum likelihood and linear mixing models. First qualitative results using TM data are shown in Fig. 3.13 for a test area in S.W. Scotland, where various mixtures of sitka spruce and lodgepole pine are present.

Perspectives For 1997

A key topic for research which has emerged from several studies during this year, is the need to integrate different approaches to land cover mapping -especially in very mixed landscape contexts. There should be a focus to integrate mixed class classification (e.g. carried out by fuzzy neural networks) with spectral mixture modelling. This topic will be tackled partially within the FLIERS project and also within some of the institutional work. The FLIERS project will also involve development of advanced visualization tools which can aid in the understanding of the different approaches to landscape mapping.

A further need is to develop syntactic image processing methodologies to exploit structural information from imagery as the spatial resolution of imaging sensors improves. The new generation of very high resolution systems giving imagery with less than 5m. ground resolution will permit major advances in topographic mapping and monitoring of urban environments. However new software tools are needed in order to exploit the complex structural information available in such imagery. It is expected that some progress will be made in this direction in the coming year if support for new actions to integrate machine vision techniques in remote sensing is forthcoming.

3.7
Third Party Work: POP-Sicily Project

Summary of Objectives

- Develop and apply methods for the detection and control of soil erosion
- Analyse coastal dynamics (erosion and sedimentation) Make the maximum use of remote sensing and GIS tools for the first two objectives

1996 Milestones

March *Technical Workshop "POP Sicilia - Cartografia Tematica, Morfologia delle Coste, Erosione del Suolo e Gestione dei Sedimenti", held in Palermo (22 March 1996)*

April *Field Campaign: land degradation and soil cover characterization, including forest*

July *Field Campaign: as above, plus coastal recognition.*

Nov. *Field Campaign: coastal areas*

Dec. *Final Report preparation*

1996 PROGRAMME OF WORK

Introduction

The POP (Progetto Operativo Plurifondo) Sicilia Project has been carried out in 1995 and 1996 in collaboration with Regione Siciliana, and the universities of Palermo, Messina and Catania. In the framework of this project the EMAP Unit was responsible for modelling and assessing soil erosion and land degradation phenomena, and for coastal sedimentation and evolution monitoring and mapping.

The study areas (Figure 3.14) are two catchment areas and the coastline corresponding to their outlets. They are: 1) the Timeto catchment (100 km^2), and 2) the Simeto catchment (4200 km^2) the largest catchment area in Sicily.

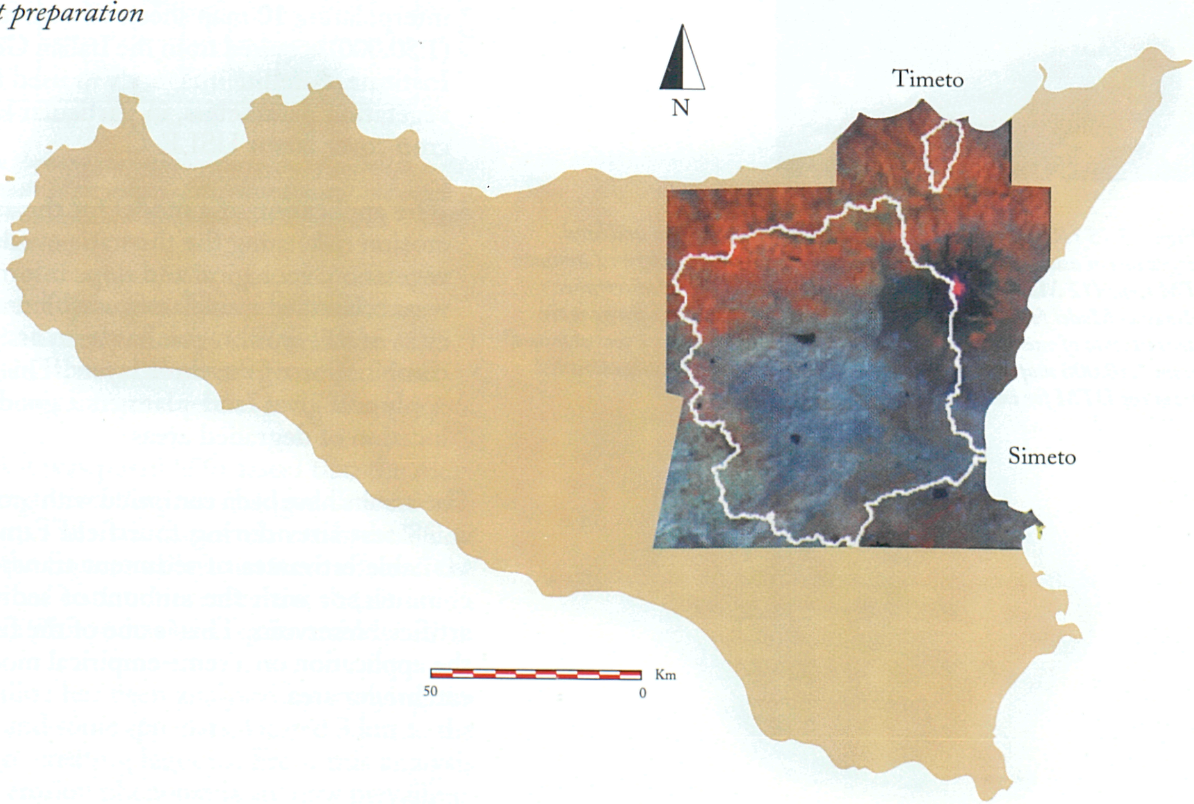
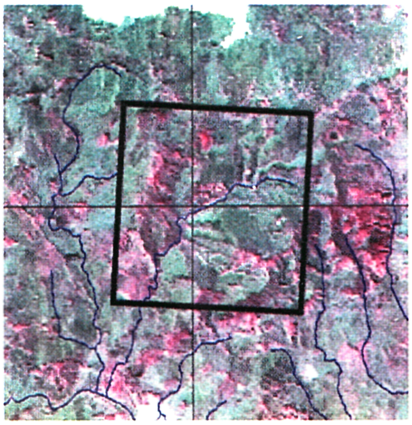
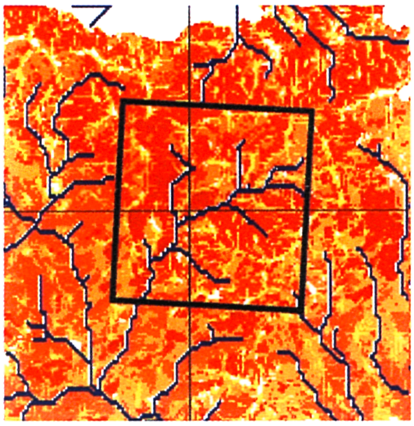


Figure 3.14 : Location of study areas. The background is a mosaic of two Landsat TM scenes (bands 4-5-3), recorded on 15 May 1994 and 22 May 1994. They have been atmospherically and geometrically corrected.



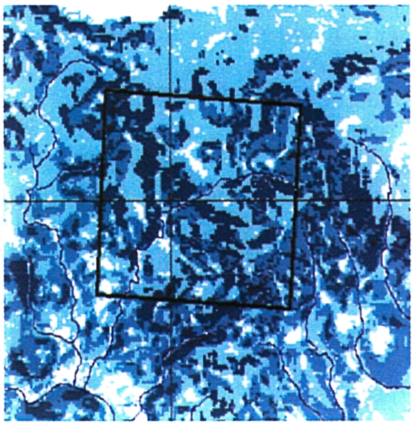
Spectral Unmixing

Combination of bands representing the abundance of parent material and shadow components. Degraded areas are coloured in magenta



Soil loss (KG/SQM year)

0
0.01 - 0.09
0.1 - 0.19
0.2 - 0.29
0.3 - 0.39
0.4 - 0.49
0.5 - 0.59
0.6 - 0.69
0.7 - 0.79
0.8 - 0.99
1 - 1.99
2 - 4.99
5 - 9.76



Soil erosion risk

inexistent
low
medium
high
very high

Figure 3.15 : Results of the methods applied for soil erosion and land degradation assessment and mapping: a) spectral un-mixing on Landsat TM scene (12 March 1994); b) Soil Erosion Model for Mediterranean Areas; c) Model for Soil Erosion Risk assessment. The black frame is the delimitation of one of the test sites. The hydrographic network was obtained from 1:50,000 maps for images (a) and (c) and automatically extracted from the DTM for image (b).

Soil erosion modelling and land degradation assessment

The study concerning soil erosion by water was carried out using three different approaches. These are:

1. Spectral mixture analysis of Landsat TM images. This method assumes that the spectral values of an image are produced by the linear mixing of a limited number of surface elements ("endmembers"). In the case of the Sicilian landscape, the main endmembers are: green vegetation, dry vegetation, developed soil, parent material and shadow. The analysis of the images based on this set of endmembers (in particular the last two), allows the identification of degraded areas with an acceptable degree of accuracy.

2. The application of a semi-empirical model, the Soil Erosion Model for Mediterranean Areas (SEMMED), in a GIS environment and using remotely sensed data. This model provides a yearly soil-loss estimate by comparing splash detachment by rain and run-off transport capacity. SEMMED has its physical basis in the Morgan, Morgan and Finney model (MMF - 1984) and runs with spatial data sets dealing with pedology, precipitation, elevation and vegetation. Pedological data were obtained using the Soil Map of Sicily (1:250.000), and by creating a database containing the values of input parameters (bulk density, water content at field capacity, depth of the "A" horizon, K-sat etc.) for each soil type. Meteorological data for 430 recording stations over a 26 year period were provided by the JRC HYDRE Project, aggregated data were interpolated for producing contour maps of yearly average rainfall and daily average rainfall. A digital elevation model was obtained by joining and interpolating 10 map sheets of contour lines and points (1:50.000) acquired from the Italian Geographic Military Institute. Satellite imagery was used for estimating the vegetation parameters, in particular land cover and the crop cover factor USLE-C.

3. The application of a model for the assessment of soil erosion risk, using the thematic overlay technique with vegetation, geological and slope information. Each layer was reclassified into classes of different risk. A different class of soil erosion risk has been assigned to each combination of the three layers. This model is easy to apply and gives land-planners a good overview of the location of degraded areas.

The results have been compared with ground data collected at 28 test sites during four field campaigns, and with available estimates of sediment transportation in water channels, or with the amount of sediments trapped in artificial reservoirs. This is one of the first experiments of the application on a semi-empirical model on a very large catchment area.

Coastal sedimentation and evolution monitoring

The study consisted of two parts:

1. Monitoring sedimentation in river plumes. This was carried out by analysing CZCS images recorded in 1979/80 for the outlet plume of the river Simeto. Due to the resolution of CZCS images it was not possible to use the images for the outlet of the smaller watershed. The images were provided by the SAI's Marine Environment - Ocean Project Group where they had already been processed for calculating the concentration of pigments.

The correlation between monthly average concentration of pigments in the area of interest, precipitation and measured run-off was examined. Correlation between the concentration of pigments and suspended sediment transport at the monthly scale was also examined (Figure 3.16). An analysis of daily data was then carried out, but, even though CZCS images are available daily, due to unfavourable atmospheric conditions it was practically impossible to acquire complete series of data in order to study daily trends between pigment concentration and precipitation or run-off.

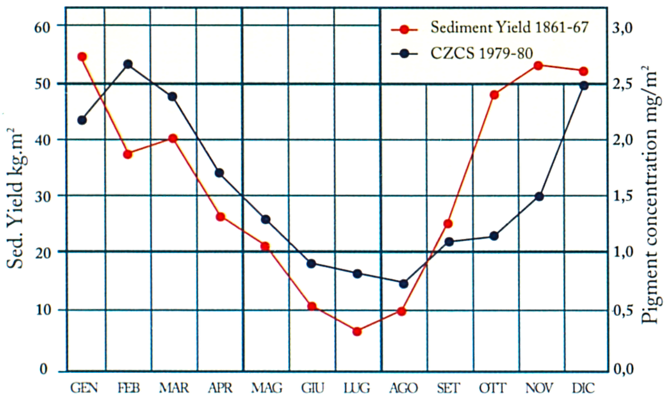


Figure 3.16 : Diagram showing the monthly variation of sediment yield (measured 10 km upstream of the mouth of the river Simeto) and mean monthly pigment concentration calculated from CZCS images (1979/80) covering the plume of the river.

2. Monitoring coastal dynamics. This was studied by digitizing an historical set of maps (1868 - 1924 - 1967) and superimposing the coastlines to geo-referenced SPOT Panchromatic images recorded in 1986 and 1996.

From this analysis it was possible to assess that the morphology of the Simeto coastline has changed dramatically over the past century. The main causes relate to hydrological improvements in the Simeto valley that have affected the position of the rivers' outlet. Nevertheless, the situation between the years 1986-96 has been quite stable.

The Timeto coastline has been analysed by studying the outlet of the river and some spit-bars, located 3 km to the east, and which are creating lagoons. From this analysis it can be said that erosion phenomena are now prevailing. These are caused by reduced sediment transportation from the inner part of the basin, due to management works on the river bed. This has had the effect of eroding the coastline by 220 m in the last 60 years. The lack of suspended sediments is causing deep erosion phenomena in the spit-bars (Figure 3.17). These phenomena have been accelerating in the last years and a shift of 40 meters has been estimated for the period 1986-87.

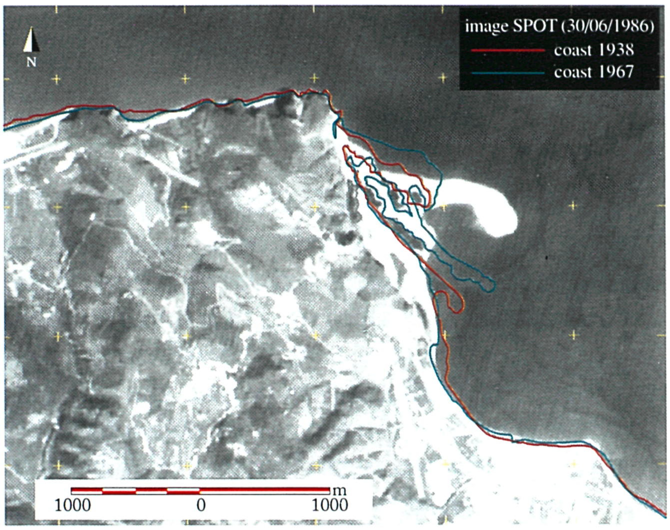


Figure 3.17 : Historical analysis of coastal dynamics at Capo Tindari (Sicily). The red line shows the coast in 1938, the green line in 1967 and the background is a SPOT panchromatic image (30/06/86).

Perspectives for 1997

The POP-Sicila work was completed on-time in 1996, however the techniques are widely applicable, and EMAP intends to further explore the combined use of modelling and remote sensing in the context of dedicated Geographical Information Systems.

Marine environment

In 1996 the Marine Environment Unit (ME) invested considerable effort in improving techniques for processing and deriving biophysical data from measurements made by satellite-based sensors. This involves a truly multidisciplinary approach. The final aim is to provide the scientific and managerial community with access to high-quality information regarding several aspects of the oceanic ecosystem, water quality in the coastal zone and the dynamics of the shoreline.

Specific studies using satellite data in the visible and near-infrared have been extended to provide better characterisation of the European regional seas, using data from the Coastal Zone Colour Scanner (CZCS) which still represents a unique data set for marine studies although its operation ceased 10 years ago.

In 1996, however, a new era for ocean colour started with the successful launch of various sensors. Notably the Modular Optoelectronic Scanners (MOS), German imaging spectrometers operating on board the PRIRODA-module of the Russian space station MIR, and on the Indian satellite IRS-P3 and the Japanese Ocean Colour and Temperature Sensor (OCTS) on board the satellite ADEOS, launched in August 1996, provided new data, introduced new challenges and also new possibilities for monitoring and management of the marine environment; the global coverage of the ocean at a spatial resolution of 700 m by OCTS for example, offers far more appropriate data sets for coastal studies than those previously available from the CZCS.

The Marine Environment Unit working with a number of space agencies began an initiative to promote the use of these new data in European waters. This work built on the Unitís past experiences with the OCTOPUS programme.

Operational use of the data from these new ocean colour sensors in coastal / shelf waters will require significant efforts in calibrating the sensors and validating the derived products. Throughout 1996 this was the focus of the CoASTS programme; operational throughout the year, CoASTS has been recently extended to new European sites through a concerted activity with other European experts.

Investigating the influence of physical and meteorological driving forces on important fishing grounds such as the Nothwest Africa and the Benguela upwelling systems, infrared data archive derived from the Advanced Very High Resolution Radiometer (AVHRR) has been significantly extended to provide total cloud coverage as well as three classes of clouds around the African continent. The detection of mesoscale features and subsequent time-series analysis clearly demonstrate that environmental parameters cannot be neglected in predictive models of fish recruitment in the coastal area at large.

In response to urgent needs from the Commission and other governmental institutions, the Unit also started work on possible operational studies using satellite data for the management of the coastal zone. This activity is strongly supported by the Centre for Earth Observation (CEO) (see chapter 7). In the first half of the year the Unit concentrated mainly on a review of data bases, models and Geographical Information Systems (GIS) needed to build a coastal zone Decision Supporting System (DSS). The second half of the year saw two specific case studies addressed; one in Thailand concentrating on the use of the coastal zone, and one in Sicily examining coastal degradation.

A further important objective of the Marine Environment Unit is the promotion of the use of marine remote sensing data by demonstrating that with new tools high level 3 dimensional data fields may be derived from the remotely sensed surface related data. This work demonstrates impressively the potential of using remotely sensed observations for reconstructing flow structures in ocean circulation, and to make in this way the result of simulation computations more reliable.

During 1996 the Marine Environment Unit's web server has been greatly enhanced. The server which can be found at URL: http://me-www.jrc.it/ now has a homepage, employing a graphical user interface which provides links to relevant information and publications as well as allowing remote users to browse the unit's comprehensive Ocean Colour and Sea Surface Temperature archives.

An Information Section describes the scope of the ME unit, and a Publications Section has been created to allow relevant published material to be made available. A Miscellaneous Section includes non published work, and a Navigation Section provides links to related internet resources.

A set of interactive visualisation and analysis tools have been developed for the OCEAN archive of historical Ocean Colour data, and the CORSA archive of Sea Surface Temperature data. It is possible to navigate the ocean colour and SST archives to view standard reduced resolution annotated browse products of the available data. In addition the server includes tools which allow the remote user to interrogate the archive to specify geographic regions of interest, to generate customised images at high resolution, to create animation sequences and time series, and to interrogate the trend in ocean colour or SST over time.

Key features include:

- Intuitive and consistent user interface.
- Browsing of individual day images.
- Browsing of weekly, monthly, seasonal, and annual average images.
- Trend analysis
- Area selection and zooming of images to full resolution.
- Animation and time series generation.

The web server has been developed using a number of different programming languages and techniques. The browse images are viewed using standard web clients such as Netscape and Microsoft Internet Explorer. The HTML is generated using CGI Perl scripts and C programs access a number of ancillary files. Graphics in the form of GIF format files are generated on the fly using the Utah Raster Toolkit, and Ghostscript.

Providing such a web server means that any remote user connected to the Internet with a web client is able to view the ME unit's data sets, without the need of any dedicated hardware or software. Currently around 2500 accesses a month are made to the homepage alone, this compares to a total of around 40 users who have received OCEAN data, and software, through the Application Demonstration Programme. This obviously includes casual visitors, however a search using Alta-Vista reveals almost a thousand web sites with a link to the Marine Environment Unit homepage.

It is clear that by making the data sets more easily accessible to a wider community, the server has succeeded both in increasing the awareness and promoting the use of the data.

4.1

Calibration and validation activities

Summary of objectives

- The calibration of ocean colour sensors.
- The validation of satellite derived products through the use of relevant in situ data.

1996 Milestones

- Twenty field measurement campaigns;
- Intercomparison experiments to evaluate accuracy of absolute calibration of optical instruments used in the field;
- Evaluation of short term bio- fouling effects on under-water optical radiometers;
- Modelling of atmospheric/marine radiance.

1996 PROGRAMME OF WORK

Introduction

Satellite Imagery has long played an important role in the investigation of the marine ecosystem, as well as providing managerial information such as water quality, resources sustainability or any environmental changes of the coastline. However, any reliable application of satellite data requires that i) the sensors are properly calibrated, ii) the water leaving signals are properly processed and validated with relevant in situ data. In this respect, the calibration/validation activities of the ME Unit aim at reducing the errors in deriving water surface parameters as well as supporting the development of new value-added products from satellite. Activities in 1996 had two main foci. The Coastal Atmosphere and Sea Time-Series project, and a data gathering cruise.

The CoASTS project

The CoASTS (Coastal Atmosphere and Sea Time-Series) project, performed in collaboration of the Italian National Research Council, collects, analyses and exploits atmospheric and marine measurements for calibration/validation activities supporting space colour sensors such as OCTS and MOS.

The measurement site is located in the North Adriatic Sea (Lat. 45°18'50"N, Lon. 12°30'30"E) in a region characterised by oceanic or coastal aerosol and Case-1 or Case-2 waters, depending on prevailing winds and currents. 1996 activities concentrated on the assessment of measurement accuracy and on definition of the temporal variability of major atmospheric/marine parameters at the measurement site.

Field measurements

In 1996 CoASTS´s activities included direct measurements (i.e. obtained from field instruments) and indirect measurements (i.e. obtained from the analysis of water samples).

Direct measurements included in-water upwelling radiance and downwelling/upwelling irradiance profiles; above water downward total and diffuse irradiance; direct sun irradiance; sky radiance in the sun plane and in the almucantar; water turbidity and fluorometry; water temperature and salinity; atmospheric pressure, humidity and temperature; wind speed and direction.

Indirect measurements included High Performance Liquid Chromatography for pigments (HPLC); in-vivo absorption spectra of pigments and detritus; absorption spectra of dissolved matter (yellow substance); synchronous and asynchronous fluorescence spectra of dissolved matter; particle size distribution; total suspended matter. Typical downwelling irradiance and upwelling radiance profiles are shown in Figure 4.1. Time series of average chlorophyll-a concentrations obtained from HPLC analysis and average pigment absorption obtained at 665 nm from in-vivo analysis are shown in Figure 4.2.

Laboratory and field calibrations/validations

Absolute calibration of optical instruments is a prerequisite for subsequent calibration and validation activities. As the ocean colour data sets considered are global in nature, it is also a prerequisite that the instruments used by CoASTS are comparable with those used by other projects around the globe.
To ensure this, the CoASTS instruments were first calibrated using internationally recognised standards (a FEL-1000W NIST traceable lamp for irradiance calibration, and this lamp coupled with a halon 99% reflectance panel for radiance calibration), then compared in a series of experiments with instruments operated by DLR (Deutsche Forschungsanstalt für Luft-und Raumfahrt), LOA (Laboratoire d'Optique Atmosphèrique (Lille, France)), NASA (National Aeronautics and Space Administration), and NIST(National Institute of Standard and Technology).

The ME / DLR intercomparison of the atmospheric and marine radiometers showed differences of less than 2% for irradiance measurements and less than 10% for radiance measurements. Results are satisfactory considering that the two laboratories rely on different standards (ME refers to NIST while DLR refers to PTB (Physikalisch Technische Bundesanstalt)).

A second intercomparison experiment, performed by NIST and ME, using underwater optical radiometers for Sea WiFS/OCTS calibration/validation activities showed differences within 2% for both radiance and irradiance data.

Collaboration with NASA and LOA, using a radiometer for sky radiance measurements, showed differences within 5% between ME and NASA/LOA data. This result is also satisfactory considering that calibration was performed using different techniques. JRC used a FEL-1000W lamp coupled with a reference panel, while LOA and NASA used different integrating spheres. Figure 4.3 shows results. Figure 4.3. Ratio between JRC and NIST derived radiance calibration factors.

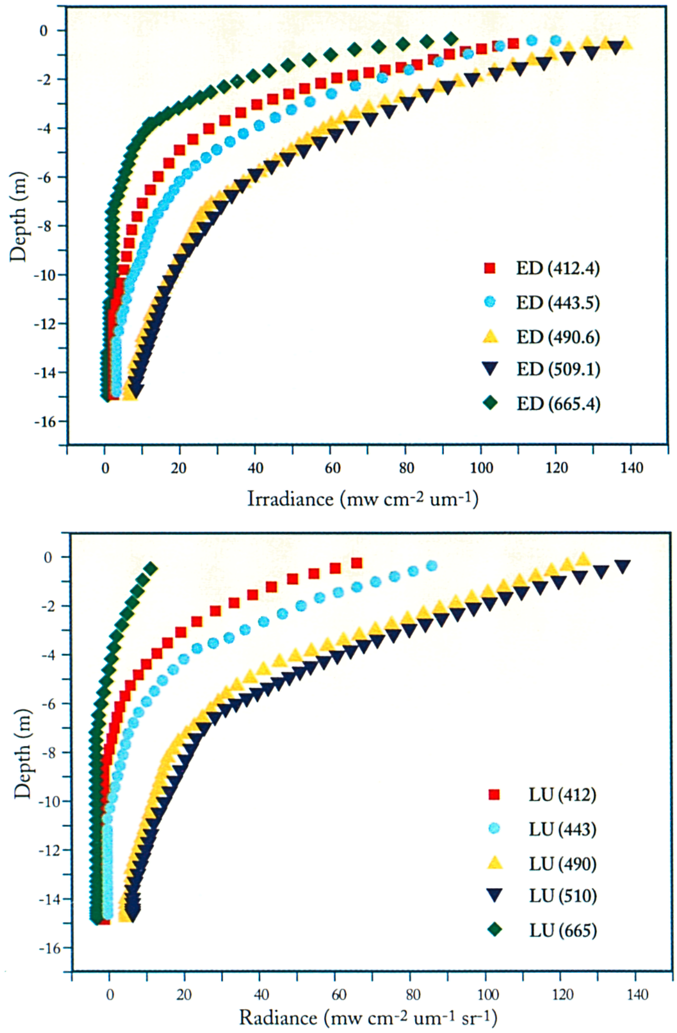


Figure 4.1 : Typical downwelling irradiance and upwelling radiance profiles taken at SeaWiFS center-wavelengths.

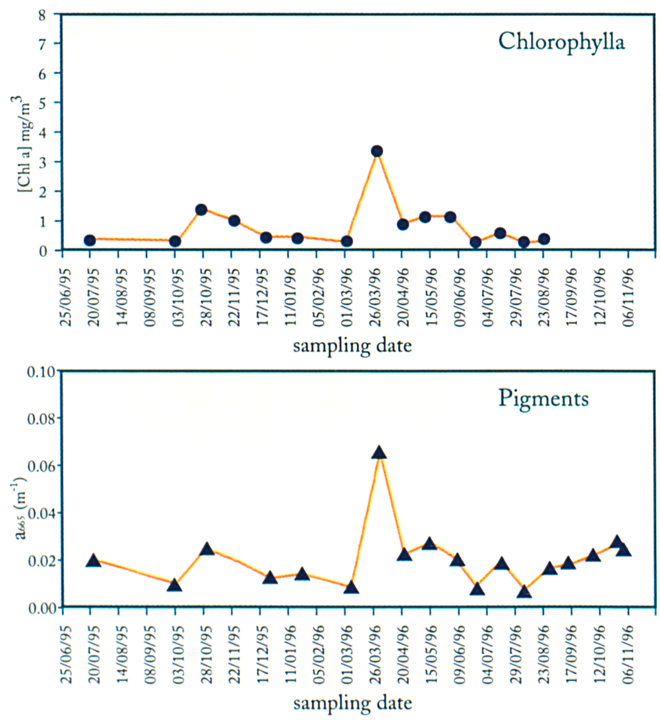


Figure 4.2 : Average chlorophyll-a concentration and pigments absorption at 665 nm.

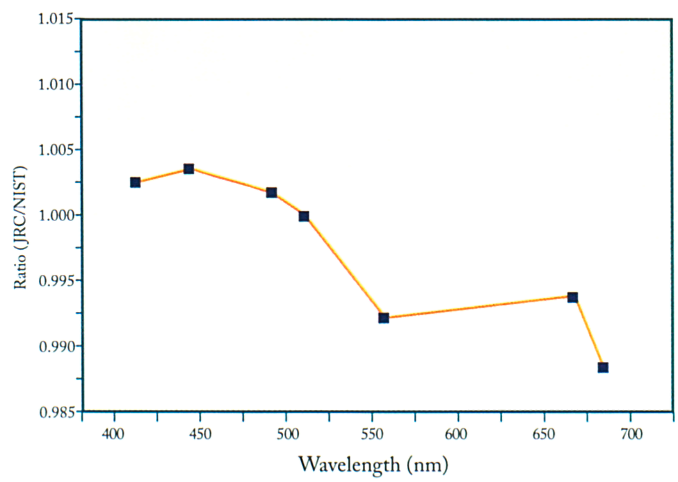


Figure 4.3 : Ratio between JRC and NIST derived radiance calibration factors.

The biological fouling experiment

In situ instruments in the marine environment are particularly prone to biological fouling, i.e., surface colonisation by bacteria and the subsequent attachment and growth of algae. This of course affects the instruments' performance. In 1996, the Unit evaluated the short-term (a few weeks) bio-fouling effects on underwater optical radiometers, and also examined the effectiveness of an anti-bio-fouling compound. This compound increases the slipperiness of surfaces making it more difficult for surface colonisation. The experiment was carried out with the Goddard Space Flight Center (NASA).

Typical deployment times for the CoASTS instruments are three weeks or so. Over such a time period two optical radiometers and glass samples were deployed at 6m depth (Figure 4.4). One of the radiometers was coated with the anti-bio-fouling compound, the other was untreated. Half of the glass samples were coated with the anti-bio-fouling compound and the remaining half were left untreated. Results showed progressive decrease in transmittance; up to 3-4% in the blue wavelengths, and 1-2% in the red. However, No significant difference was observed between the decrease in transmittance of the treated and untreated glass samples, which does tend to raise the question of the effectiveness of the anti fouling material.

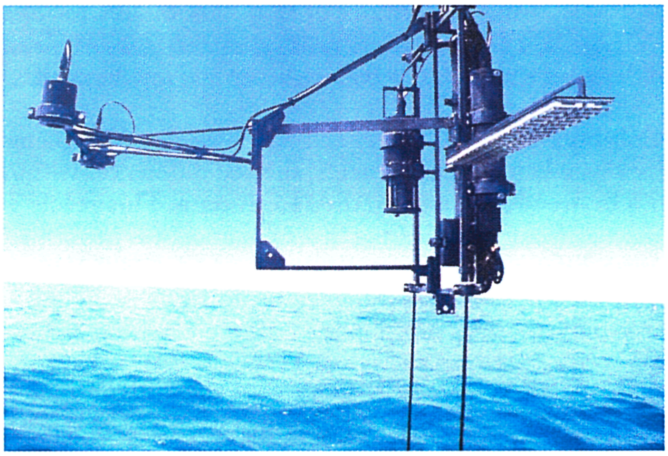


Figure 4.4 : Instrumental package used for the bio-fouling experiment.

Radiative transfer modelling

Vicarious calibration of marine space colour sensors require modelling of the radiative transfer processes in the atmosphere and sea. Such modelling requires accurate simulation of the light field. To evaluate the capability of the Monte Carlo Photon Transfer code (Pho-Tran) recently developed at SAI and validated against existing literature benchmarks, simulation of real light fields at the CoASTS measurement sites were performed for intercomparison with field data.

Sample measured, and simulated upwelling radiance profiles, for 3 different SeaWiFS bands, are shown in Figure 4.5. Differences observed when comparing measured and simulated values can be attributed to approximations made in describing the scattering properties of the water column. As such, the results obtained in 1996 lead the ME Unit to adopt Pho-Tran as a satisfactory simulator for use in the vicarious calibration work.

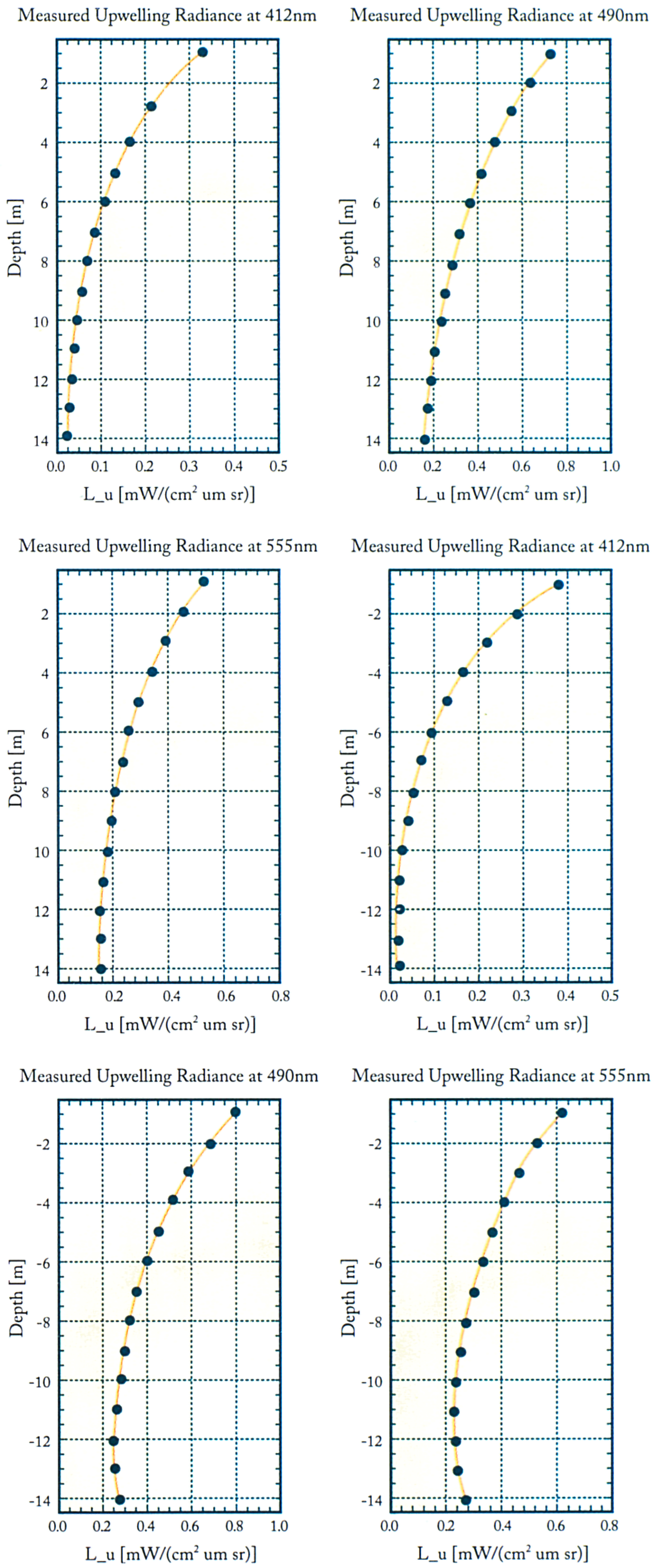


Figure 4.5 : Measured and simulated upwelling radiances depth profiles.

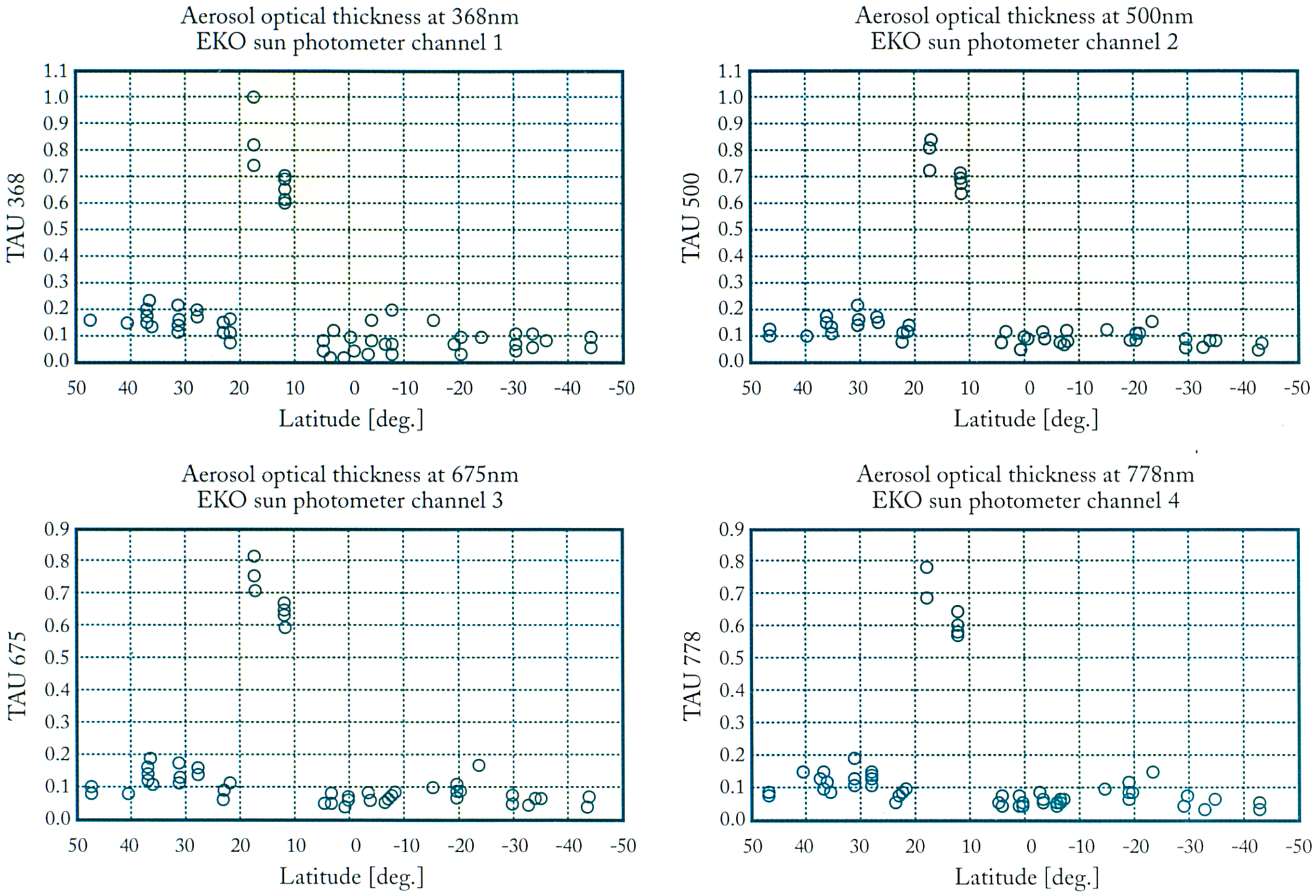


Figure 4.6 : Aerosol optical thickness at the 4 sun-photometer channels: Overall transect data.

Measurements of the aerosol optical thickness along a north-south transect in the Atlantic Ocean

The general Atlantic Meridional Transect (AMT) programme co-ordinated by Plymouth Marine Laboratory (PML) provides fundamental information for the calibration and validation of satellite remote sensing of the oceans over large basin scales. In 1996, the ME Unit undertook a campaign of optical measurements on board of the Royal Research Ship (RRS) James Clark Ross (JCR) as part of the AMT-2 scientific cruise.

A four channel hand-held sun photometer was operated across the whole meridional transect ranging from -50S to +50N degrees latitude to measure atmospheric transmittance spectra during the months of April and May 1996 and across the Atlantic Ocean.

These data are particularly useful when applying the atmospheric corrections necessary to derive satellite sensor estimates of LW ((): the water-leaving upwelling spectral radiance. The instrument used by ME operates at four specific wavelengths -368, 500, 675 and 778nm- and transmittance data at other wavelengths can be computed. Aerosol optical thickness at different wavelengths can be related to Angstromís wavelength exponent. This can be used to compute optical thickness at other wavelengths of interest.

Post calibration of the instrument was carried out at the Joint Research Centre on a clear and atmospherically stable day on the 8th of November 1996. The collected, calibrated and processed data, showing aerosol optical thickness at the four sun photometer channels, are graphed in Figure 4.6. for the entire AMT-2 cruise track in the Atlantic Ocean.

From the available aerosol optical thickness at the six visible SeaWiFS channels located at 412, 443, 490, 510, 555, and 665nm, plus one for the chlorophyll fluorescence signal at 683nm were computed. Results (excluding hazy days) are graphed for the whole transect in Figure 4.7, and for a particular day -crossing the equator- in Figure 4.8.

A general trend of increasing aerosol optical thickness at Northern latitudes is observed, and a steep rise due to strong maritime haze is observed in the Northern tropical region. The encountered atmospheric compositions also presented a large variability, ranging from purely oceanic to mixed coastal aerosols, and subject to local contamination as caused by high concentrations of anthropogenic components (in Montevideo bay) and of Sahara desert dust and suspended sand (off the North Western African coast)

The aerosol optical thickness data over a full oceanic meridional transect will be of major use in assessing atmospheric correction algorithms over large water basins, and thus lead to significant improvements in the quality of large scale oceanic observations made from space-borne sensors.

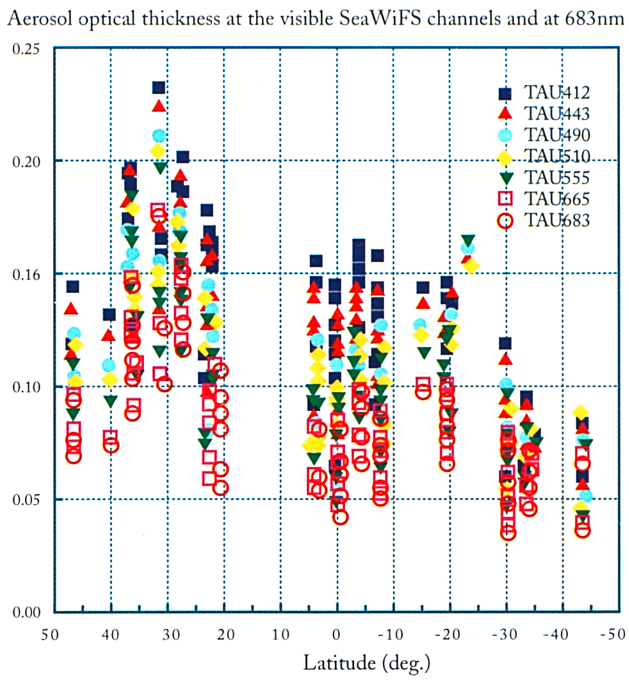


Figure 4.7 : Aerosol optical thickness, Across-the-equator plot.

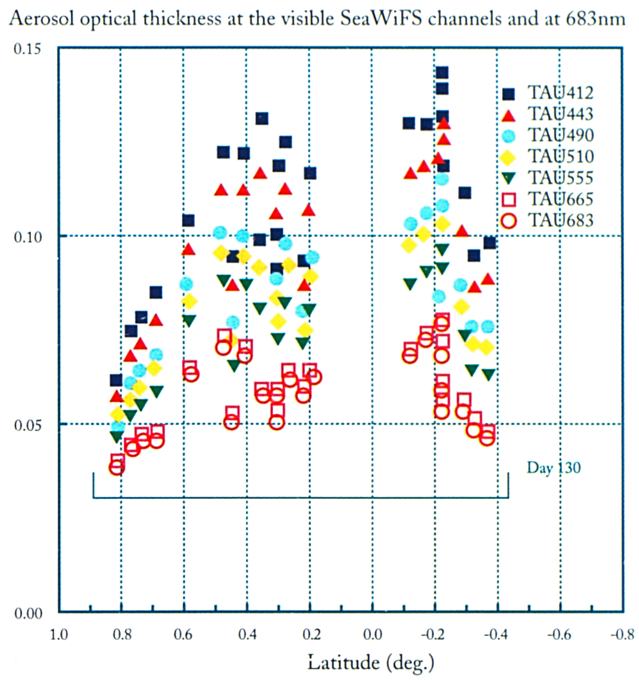


Figure 4.8 : Aerosol optical thickness, at 6 SeaWiFS visible channels plus chlorophyll fluorescence channels: Full latitudinal plot.

Bio-optical aspects of ocean colour measurements from remote sensing

The interpretation of the spectral signature of the light upwelled from the water surface is difficult since many processes and many compounds contribute to the light field, particularly in coastal waters. Another task within such a calibration/validation activity is therefore i) to decompose the spectral measurement of light in the water in terms of spatial and time distribution of properties interacting with light, ii) to analyse the variability in time and space of optical properties inherent to these compounds, and finally iii) to develop models sensitive enough to validate satellite ocean colour products in European coastal areas.

A method to measure light absorption by aquatic heterotrophic bacteria

Heterotrophic bacteria with sizes peaking in the 0.4-0.7 micrometre range can form a sizeable part of the particulate organic matter in the upper layers of the ocean, thus significantly changing the underwater light field especially at blue wavelengths. Therefore, any investigations on changes of the apparent optical properties of the water requires information on the contributions to absorption and scattering of light by all material present in the water, including bacteria. To this end the ME Unit performed a number of experiments aimed at characterising these bacterial effects.

In situ collected water was pre-filtered to remove particles with diameter greater than than 0.7um. Then the samples were passed through other filters to yield filter-retained samples of particles with diameters between 0.22 and 0.7um. The optical properties of these particles were then measured. The measurements were performed in the *"transmission mode"* and in the *"reflection mode"* (Fig. 4.9) to correct for the effect of particle backscattering which is not accounted for directly when using single *"light-transmission"* measurement in standard methods for the determination of absorbance.

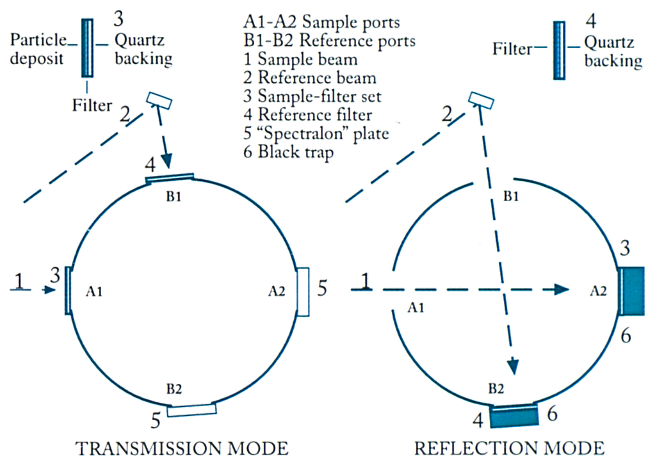


Figure 4.9

Light absorption by heterotrophic bacteria is due to the respiratory pigments, mainly the cytochrome c, displaying a characteristic absorption peak at 415 nm.

The first filtration step removes most of the chlorophyll-containing cells as shown by the absence of or a negligible red peak in the spectrum, eventhough the photosynthetic pigments were not extracted beforehand. The prefiltration procedure is not efficient enough to retain a fine detrital component which would overestimate the total bacterial absorption by as much as a factor two.

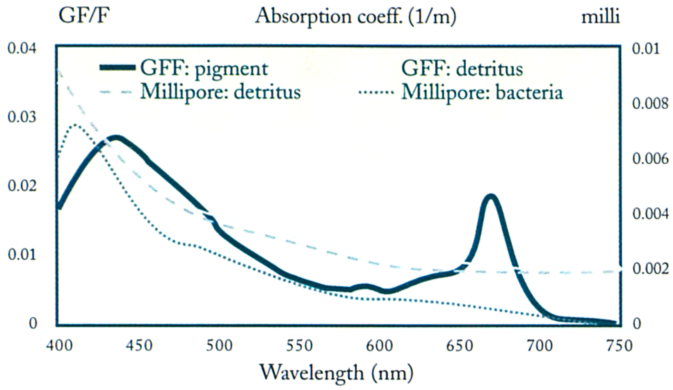


Figure 4.10 a

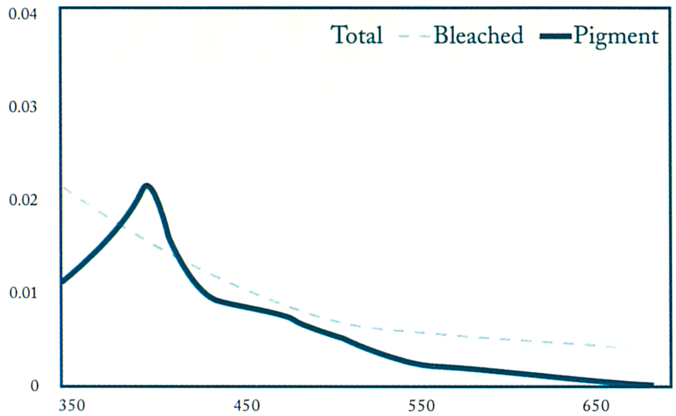


Figure 4.10 b

A comparative assessment of light absorption by chlorophyllous particle, detritus (including sediments) and bacteria in two different aquatic environments is shown in Figure 4.10. In oligotrophic water of the Gulf of Naples (Fig. 4.10a), the bacterial component contributes to 8% of the total absorption, whereas in the Lake Varese, Italy (Fig. 4.10b) the bacterial contribution is reduced to 4%. This result is consistent with lower bacterial concentration relative to phytoplankton in mesotrophic waters. It has been further demonstrated that neglecting the fine particle absorption properties in these two samples would underestimate the total particle absorption (standard Filter method) by 20% and 9% respectively.

Combining the measured absorption with published data on the backscattering: absorption ratio it is possible to include the optical properties of heterotrophic bacteria in multi-component models of radiative transfer in the water.

Bio-optical modelling in European coastal waters

This study examined the variability of the spectral absorption of Non Chlorophyllous Particles (NCP) and Coloured Dissolved Organic Matter (CDOM) using datasets from two European coastal sites, the Southern Baltic Proper and the Northern Adriatic. These two regions differ both in their basic oceanographic properties and in their relative proportions of Optically Active Components (OAC). Furthermore, the datasets illustrate the variability at different scales in both space and time, combining a series of seasonal oceanographic campaigns in the Baltic with a complete annual time series of monthly measurements at a fixed point in the Adriatic.
The data consisting of continuous measurements of spectral absorption in the range 400 to 700nm for photosynthetic pigments (CPIG), NCP and CDOM have been investigated with respect to the variability of absoption spectral shape and amplitude for the two sites selected (Baltic and Adriatic) and for the three components (CPIG, NCP and CDOM).

The contribution of the three components to the total light absorption by the water is illustrated in Figure 4.11 for three stations in each of the sites. The data show a large seasonal (Adriatic data) and spatial (Baltic data) variability in the contribution of the individual components to the total absorption. For example, although CDOM is the dominant constituent in the Baltic, the plot for station

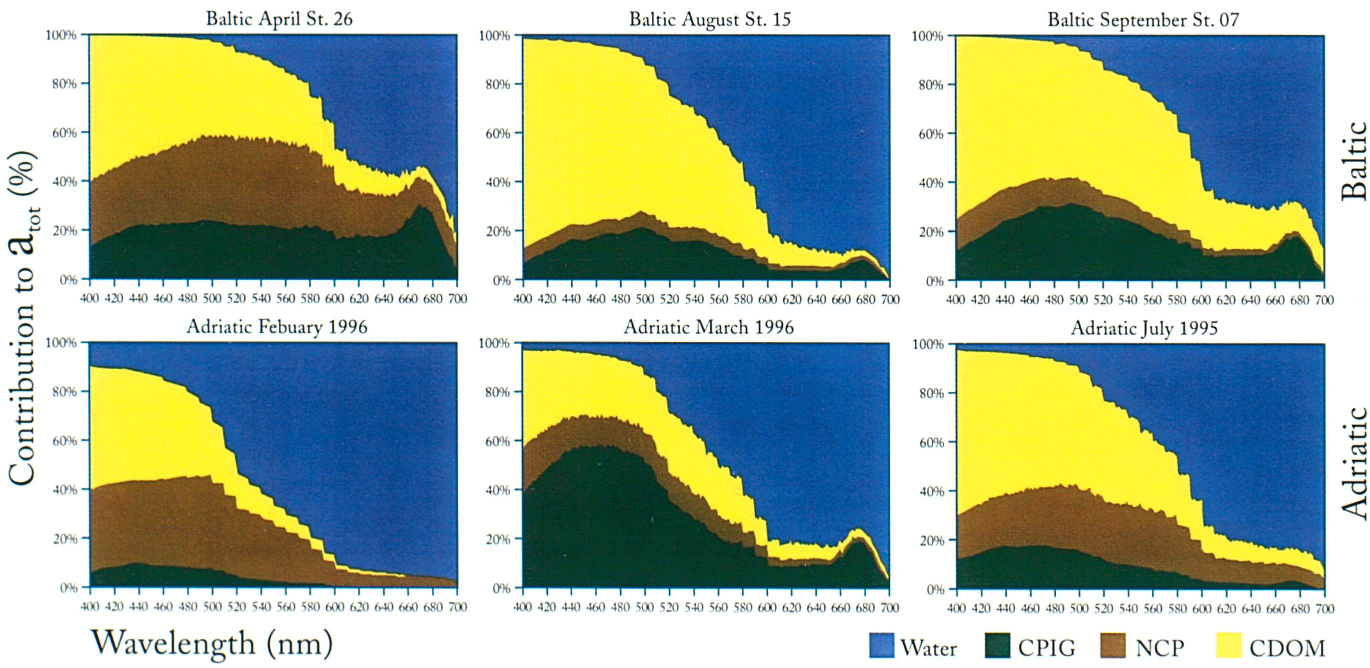


Figure 4.11

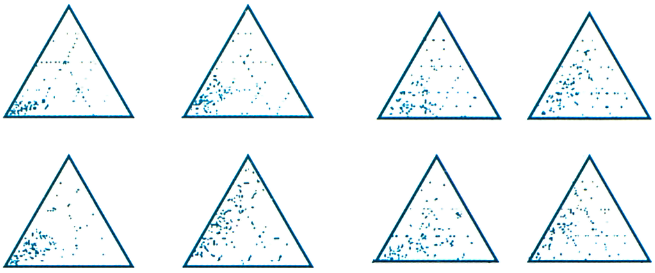


Figure 4.12

26 in April suggests a significant contribution by the NCP as well, especially in the green area of the spectrum. The Adriatic plots (February, March and July) highlight a strong seasonal variation in the absorption budget, with NCP absorption dominating in the Winter month (February), CPIG absorption in spring during the bloom period and CDOM absorbing more during the summer.

The investigation using ternary plots (Figure 4.12) has shown to be most useful in interpreting the absorption budget for specific wavelengths, e.g. channels from typical ocean-colour satellite sensors. The general picture for the two sites tend to emphasise the variability shown in the red wavelengths, which therefore may be of significant importance in reflectance modelling of Case II coastal waters. The dominance of the CDOM absorption at the blue wavelength for the Baltic and to a lesser extent for the Adriatic is quite clearly shown. For both sites, there is a slight tendency toward NCP contribution at 550nm, although neither location can be considered a sediment dominated water body. As mentioned above, the plot for 670nm shows the largest degree of variability although the values are concentrated on the CDOM-CPIG side of the plot. This technique, already proposed as a generic marine classification, shows here its value in sub-classifying European coastal waters differentiating between yellow substance-dominated and sediment-dominated water types (i.e., case II water, Fig. 4.13) from chlorophyll-dominated or case I waters.

The presented study has shown the need to independently describe the contributions of NCP and CDOM to the total absorption budget of the European coastal waters. An exponential fit to NCP and CDOM absorption and a subsequent statistical analysis on the parameters (slope) provided mean values that are is some cases substantially different to those presented in the literature, indicating that, in the frame of reflectance modelling in Case II waters, attention must be placed on accounting for NCP and CDOM individually when defining the absorption segment.

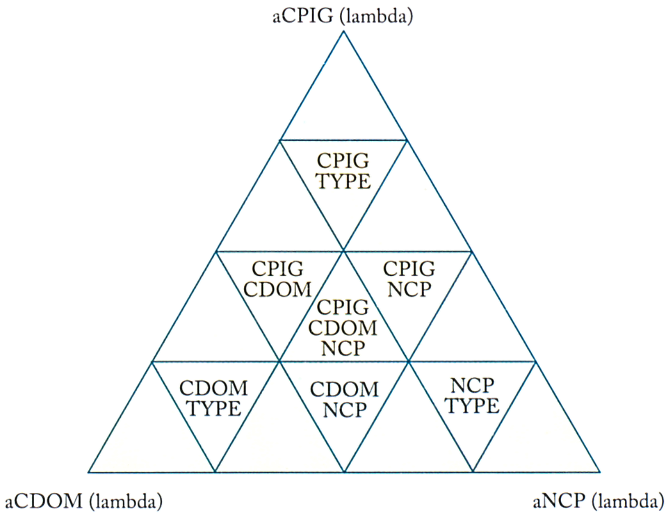


Figure 4.13

Empirical retrieval of chlorophyllous and non-chlorophyllous matter from satellite data in the Baltic Sea

Present methods for the inversion of satellite ocean colour measurements generally rely on the classical relationship between the ratio of the water leaving radiance $L_w(\lambda)$ and the irradiance $E_d(\lambda)$ impinging at the sea surface, i.e. the *"remote sensing reflectance"* $R_{rs}(\lambda)$, and the inherent optical properties (spectral absorption $a(\lambda)$ and back-scattering $b_b(\lambda)$ coefficients) of the dissolved and particulate constituents within the surface layer :

$$L_w(\lambda)/E_d(0^+,\lambda)=R_{rs}(\lambda)=f/Q\ b_b(\lambda)/a(\lambda)$$

By using reflectance ratios instead of single reflectance the uncertainty associated with the large variability of *"f/Q"* and of $b_b(\lambda)$ by particles, may be reduced. In effect, by assuming that as a first approximation f/Q is independent of λ, a R_{rs} ratio can be written as:

$$R_{rs}(\lambda i)/R_{rs}(\lambda_j) = [b_b(\lambda_i)a(\lambda_j)] / [b_b(\lambda_j)a(\lambda_i)]$$

If we express the wavelength dependency of the total back-scattering coefficient as:

$$b_b(\lambda_i)=b_b(\lambda_j)\ (\lambda_i/(\lambda_j)^N$$

the earlier equation becomes:

$$R_{rs}(\lambda_i)/R_{rs}(\lambda_j)=(\lambda_i/(\lambda_j)^N\ a(\lambda_j)/a(\lambda_i)$$
$$\Leftrightarrow a(\lambda_j)/a(\lambda_i)=R_{rs}(\lambda_i)/R_{rs}(\lambda_j)\ (\lambda_i/\lambda_j)^{-N}$$

the knowledge of N allowing to derive total absorption ratios from "remotely-sensed" reflectance ratios.

Using the Baltic bio-optical data set described in the preceding section several empirical relationships were investigated in 1996. Firstly between N (computed fitting equation 1 on in situ data) and reflectance ratios, secondly between total absorption ratios and non chlorophyllous dissolved plus particulate matter absorption (a_y+a_d) at 412 nm, pigments absorption (aph) at 443 nm and chlorophyll-like pigments concentration (Chl), respectively.

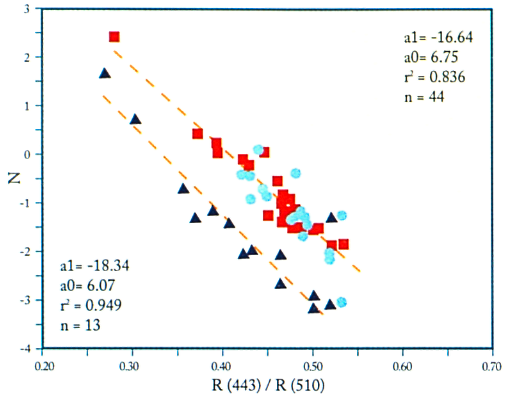


Figure 4.14 : Computed N versus $R_{rs}(443)/R_{rs}(510)$ ratio and associated linear regressions for April (triangles) and others (August = squares, September = filled circles; see text).

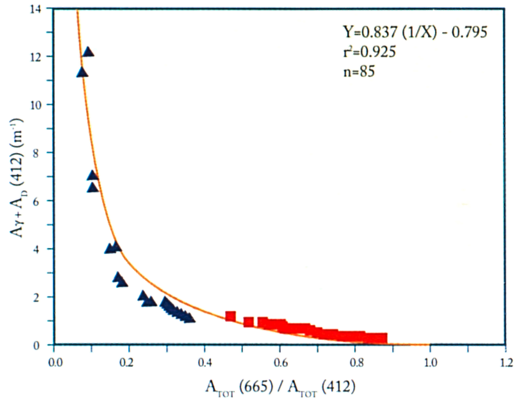


Figure 4.15 : (ay+ad)(412) versus atot(665)/atot(412) and computed relationship.

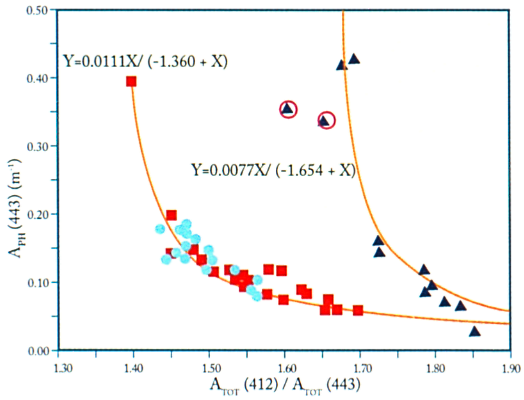


Figure 4.16 : $a_{ph}(443)$ versus atot(412)/atot(443) and computed relationships for April (triangles) and others. Two April stations (circled) were disgarded.

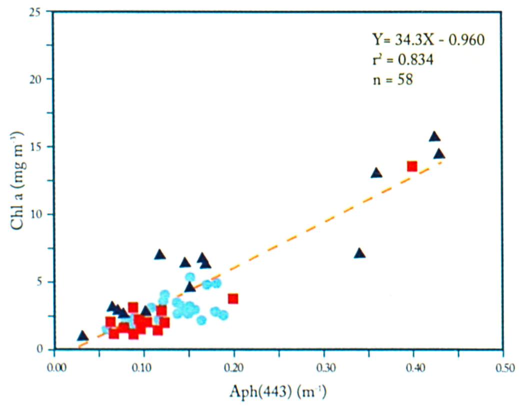


Figure 4.17 : Chlorophyll-like pigments concentration versus $a_{ph}(443)$ and associated linear regression.

The 443/510 R_{rs} ratio has revealed to be the best empirical estimator of N (Fig. 4.14) but no unique relationship could be found and the April stations, for which extremely high absorption in the blue (>1 m^{-1} at 412 nm) by dissolved organic matter (DOM) was measured, had to be treated separately.

The 665/412 total absorption ratio has been found to provide the best estimation of (a_y+a_d) at 412 nm (Figure 4.15) all stations considered.

The 412/443 total absorption ratio provided the best estimation of a_{ph} at 443 nm (Figure 4.16) but, again, April stations had to be considered separately.

A reasonably good linear relationship has then been found between the chlorophyll-like pigments concentration and pigments absorption at 443 nm (Figure 4.17).
The sensitivity of the final estimated quantities to these successive empirical steps (in particular to the N estimation) has to be asserted and validation must be effected using independent data sets for the region. The applicability of the present results is of course restricted to the investigated area.

Perspectives for 1997

In 1997, the calibration / validation activities at SAI/ME will primarily focus on two main actions:

- evaluation of vicarious calibration coefficients for ongoing satellite sensors (OCTS, MOS and possibly SeaWiFS)
- development and assessment of bio-optical algorithms applicable in remote sensing of ocean colour along the European coasts.

4.2

Ocean dynamics and biochemistry

Summary of Objectives

- Investigation of basic-scale dynamics: the Mediterranean case study;
- Improvement of models to measure marine DMS-Dimethylsulphide;
- Update of the CORSA archive to include total cloud cover around Africa;
- Comparative analyses of SST upwelling index in upwelling areas.

1996 Milestones

Differentiation of key bio-physical provinces for the Mediterranean basin.

Re-calibration of existing mathematical model of dimethylsulphide (DMS) production.

Extension of the CORSA archives.

Creation of new cloud maps for the CORSA region.

1996 PROGRAMME OF WORK

Introduction

Satellite oceanography provides an increasing awareness that the ocean interacts continuously with the atmosphere and land, leading to short-term local effects, as well as long-term climate change. The ME Unit's research in this field investigates the operational use of ocean colour (chlorophyll) and thermal data (sea surface temperature, clouds) to derive indices of relevant environmental processes such as water productivity and upwelling events.

A satellite view of some bio-physical interactions in the Mediterranean Sea

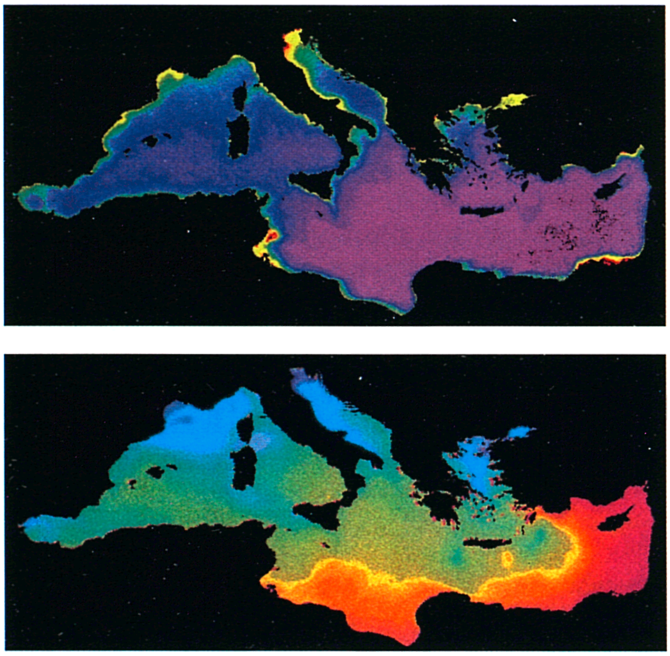
The Mediterranean Sea is a relatively small basin, representing less than 10% of the total area of the world's oceans, but is an excellent scale model of the global marine environment. It has a profound influence on weather and climate over a large region, including much of Europe, Northern Africa, and the Middle East. It provides important resources for consumption by local as well as global markets. It offers unique opportunities to study ecological relationships and forcing mechanisms for processes affecting the interaction between land, atmosphere and sea.

Climatology of the Mediterranean Sea

The compilation of historical time series of remote sensing data covering the Mediterranean Sea - primarily CZCS and AVHRR - has for the first time shown the marked space/time heterogeneity of a number of surface parameters, derived from optical and thermal indices. In particular, the variability observed in the satellite data record points at specific bio-geochemical provinces, where a significant relationship seems to exist between such indices and the climatic features of the region.

Long-term composites of chlorophyll-like pigment concentration and sea surface temperature (Fig. 4.18) were derived respectively from 2465 CZCS images and from 9396 AVHRR images. In both cases, the raw data were processed to apply sensor(s) calibration algorithms, to correct for atmospheric contamination, and to derive chlorophyll-like pigment concentration and surface temperature values. Individual images were generated for each available day, co-registered using the same geographic equal-area projection and resolution, and then averaged pixel by pixel, to compute monthly, seasonal and annual composites.

The long-term composites cover an area of 4000x2000 km^2, with a 1 km pixel size, including the whole Mediterranean basin.



pigments	(mg/m³)	purple	blue*	green	yellow	orange	red
lighter tone		0.05	0.15	0.33	0.80	1.65	4.00
darker tone		0.08	0.25	0.50	1.22	2.45	>
temperature	(C)	blue*	aqua	green 1	green 2	yellow	red
lighter tone		9-10	13	15	17	19	21
darker tone		11-12	14	16	18	20	22
							*inv tone

Figure 4.18 : Mediterranean Sea annual composites of CZCS (1979-1985) pigment concentration in mg/m³ (upper plate) and AVHRR (1982-1990) temperature in (C (lower plate).

Marked differences appear in both the CZCS and the AVHRR mean annual composites between western and eastern sub-basins, inshore and offshore domains, as well as northern and southern near-coastal areas. The mean annual pigment concentrations and surface temperatures show that the transition between the western and the eastern regime corresponds with the line of narrow straits going from the Sicily Channel, to the Strait of Messina and the Strait of Otranto. In the annual means, the western basin is characterised by higher pigment concentrations and lower temperatures than the eastern basin (where the Aegean Sea represents a notable exception).

The spatial gradients in surface colour differentiate between the mainly oligotrophic basin interior and the areas of high pigment concentration along the basin margins. These are influenced by persistent mesoscale dynamic features (e.g. permanent gyres and coastal filaments anchored to geographical features), by river plumes (e.g. those of the Ebro, Po, Rhone, Nile), and by extensive coastal runoff. The surface temperature gradients, instead, point to a smoother transition between the inshore and the offshore domain, but also show peculiar dynamic features along the basin margins, particularly in the north-western basin.

The similarities of pigment and temperature dynamics in the Ligurian, Provençal and Balearic basins and in the Adriatic Sea is evident for both coastal zone and open sea. Even the northern Aegean Sea seems to have characteristics similar to those of the north-western basins. This suggests that the rim of enhanced pigment values and lower temperatures around the northern part of the Mediterranean might be associated with the impact of runoff from the northern continental margin and with river discharges (i.e. both a direct impact due to the sediment load and one induced on the planktonic flora by the associated nutrient load), as well as with the vertical mixing due to the prevailing winds (i.e. the Mistral over the north-western Mediterranean, the Bora over the northern Adriatic and the Etesians over the Aegean). Therefore, atmospheric forcing would appear to play an important role in establishing the observed space/time distribution of water characteristics.

Differentiation of bio-physical Provinces

Given the pixel by pixel correspondence of the two long-term composites, a new multi-band image could be constructed in which the colour and temperature histogram-matched images constituted two different bands. An unsupervised classification of such a two-band image highlights the patterns inherent in the data (Fig. 4.19).

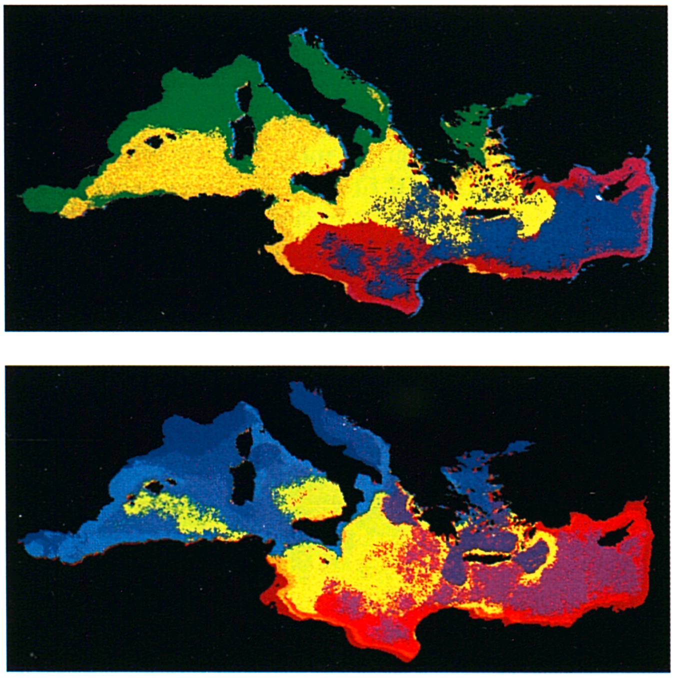


Figure 4.19 : Unsupervised classification in 8 classes (upper plate) and in 16 classes C (lower plate) of the Mediterranean Sea surface waters characteristics, derived from a combination of the annual composites of CZCS (1979-1985) pigment concentration in mg/m³ and of AVHRR (1982-1990) temperature in (C. The arbitrary colour coding highlights the different classes.

Such a classification of Mediterranean waters, confirms the peculiarities of the "northern" coastal zone. The areas influenced by the main northerly winds are particularly evident in the 16 class image (note how the upwelling areas of western and southern Sardinia, as well as that of southwestern Sicily, also linked to Mistral outbreaks, are highlighted by the classification). Dynamic features such as the incoming Atlantic jet, the northward current of Ionian waters entering the Adriatic on the eastern side of the Otranto Strait, the string of mesoscale gyres, the Western Cretean gyre and the Rodhes gyres in particular, also appear as having distinct properties.

To conclude, the testing of the hypotheses on the relationship between geographic and climatic factors and biogeochemistry, using the Mediterranean as a scale model of the ocean, should exploit the availability of data from various synergistic sensors, providing information on surface colour and pigments (e.g. OCTS and MOS, and eventually SeaWiFS), surface temperature and dynamics (e.g. AVHRR, and Along Track Scanning Radiometer ATSR, for calibration samples), surface roughness and forcing (e.g. sample imagery from ERS sensors). The merging decade-long remote sensing time series provide the opportunity to put point-measurements from field studies into a broader perspective, and help define proper strategies for handling the larger volumes of data that will be available from international programs such as the Earth Observing System (EOS) and the Centre for Earth Observation (CEO), as future missions such as the EOS Observatories and ENVISAT (deploying sensors like MODIS and MERIS) evolve.

Investigation of dimethylsulphide (DMS) marine cycling: Model inter-comparison and validation.

Goals

An existing mathematical model of dimethylsulphide (DMS) production in the Southern ocean, originally developed in collaboration with Griffith University, Australia, the Space Applications Institute and Environment Institute, JRC, and the University of Tel Aviv (referred to as GMSK model) has recently been extended by Griffith University to include the effects of light and temperature on phytoplankton growth.

Work during the last year at ME, has been aimed at linking the GMSK model to a primary production model which uses ocean colour satellite imagery to estimate algal photosynthesis in the euphotic zone. This extended model, which we refer to as DMSFLUX-Sat model, includes vertical variability over the mixed layer depth and, because of its satellite imagery input is able to take into account sharp spatial and temporal variations in biomass.

Preliminary testing of this integrated model (DMSFLUX-Sat) has been undertaken by comparing the results of the analysis of the data collected on a cruise in the North Atlantic in 1992, on board the Canadian vessel "Hudson".

The approach taken has been to re-calibrate the GMSK model, already successfully applied to Cape Grim data (Tasmania), to North Atlantic conditions, and compare the results with the experimental data and numerical output from DMSFLUX-Sat.

Hudson data description.

The research activities for the Hudson campaign (Sept-Oct 1992) were developed by the Bedford Institute of Oceanography, Canada, the Space Applications Institute and Environment Institute-JRC.

The aim of the measurements programmes on board the Hudson during its two transits of the North Atlantic basin and in the Northwest African upwelling area, was to obtain the main biological, oceanographical and atmospheric parameters in these areas, as a part of the international Joint Global Ocean Flux Study (JGOFS). In particular, estimation of biomass and primary productivity turns out to be of particular interest for the purpose of DMS investigations. In fact, in order to better understand the biological production of DMSP and DMS and their cycling and consumption in the euphotic zone, data were collected on plankton species, grazing dynamics of zooplankton, bacterial concentration and activities.

Re-calibration of the GMSK model

Re-calibration of the GMSK model has been carried out using data collected at the first North Atlantic transect of the Hudson cruise. The second data subset, i.e. those collected during the second (return) transect, has then be used to carry out preliminary validation of both models. The re-calibration steps of GMSK model are:

- Changing the forcing functions, wind speed and sea surface temperature. Wind speed data collected during the cruise were elaborated using a fifth order polynomial regression. In addition, the wind speed function of the model was then extended to the other days of the year using the ECMWF meteorological data base, giving monthly averages on which the wind speed function is then fitted. In the GMSK model, Sea Surface Temperature (SST) is modelled as a periodic function of the year based on maximum SST (of the year), minimum SST, and the Julian day in which max SST occurs. Those three data sets have been extracted from the sea surface temperature data archive at SAI-ME (CORSA project).

- Changing model parameters. In order to make the GMSK model run under typical conditions of the North Atlantic area, GMSK model parameters have been set to the same values selected for the biological part of the DMSFLUX-Sat model.

- Changing initial conditions (using 1 single day data). All the state variables of the model have been initialised using "*in situ*" data relative to Julian day 263 (20/09/92), which is the first day transect of the Hudson cruise. The model has been run for 14 months in order to get a "*steady state*" situation.

- Comparing results with *"in situ data"*. Predictions of the GMSK model for Julian days 264-274 (21 Sept.-1 Oct.) have then been compared with the Hudson cruise data relative to the first transect (Fig. 4.20). The level of agreement between the two data sets, i.e. model predictions and *"in situ"* data, was given by Minimum Least Square analysis applied to three out of the eight state variables of the model, Phytoplankton (P), Zooplankton (Z) and DMS. Since all parameters of the model (32 in total) affect to some extent these three variables, a subset of the three most influential ones were selected for this analysis. In addition, a 3-dimensional 5-levels grid has been constructed, where each of the three selected parameters can take on 5 values.

The calibration process of the GMSK model has been reasonably successful in generating the surface chlorophyll (Fig. 4.20a). However, it is clear that the high variability in DMS concentration in the water (Fig. 4.20b) cannot be propagated with the actual model using a time step of one day which may be inadequate to account for all bio-chemical processes affecting DMS concentration in the water.

Models validation

The data from the second transect (2-10 Oct.) of the Hudson cruise was used to compare both GMSK and DMSFLUX-Sat model predictions (Fig. 4.21). Since the amount of data available was not enough to derive an accurate measure of integrated chlorophyll or DMS concentration, comparison has been carried out considering only concentrations at surface.

For chlorophyll (Fig. 4.21a), the DMSFLUX-Sat model seems to be more successful than the GMSK in predicting the "right" concentrations at surface, although an increase

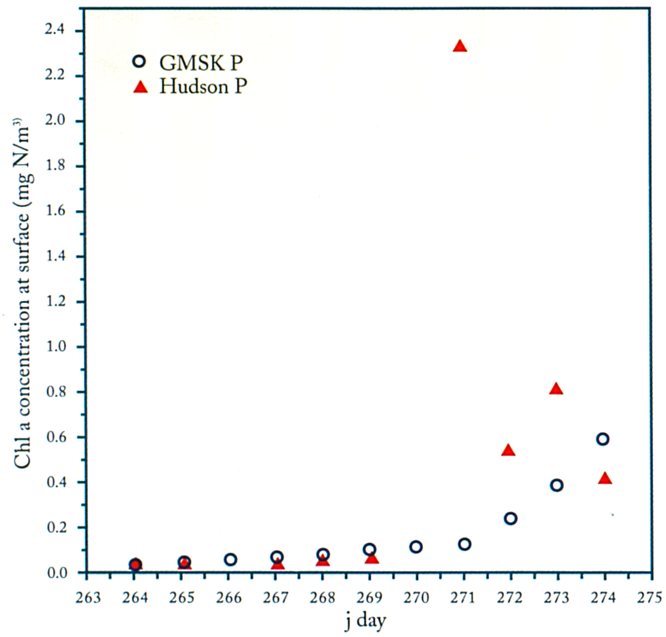


Figure 4.20 a

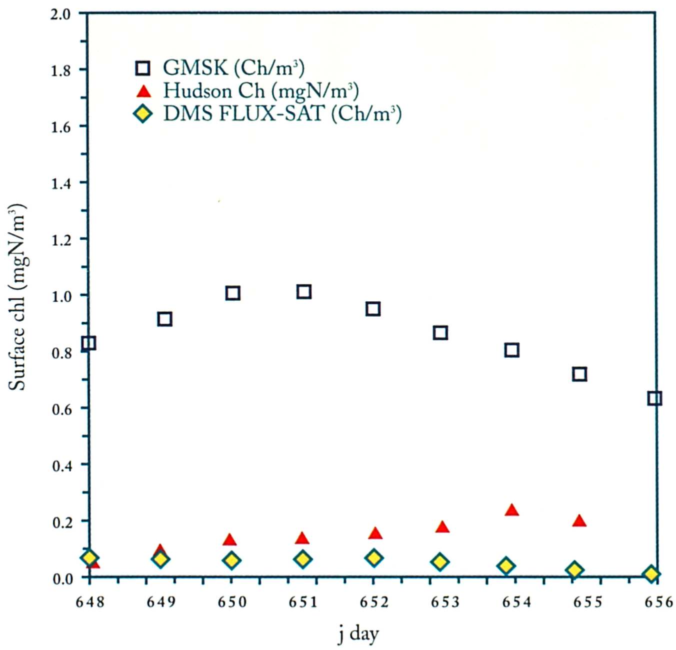


Figure 4.21 a

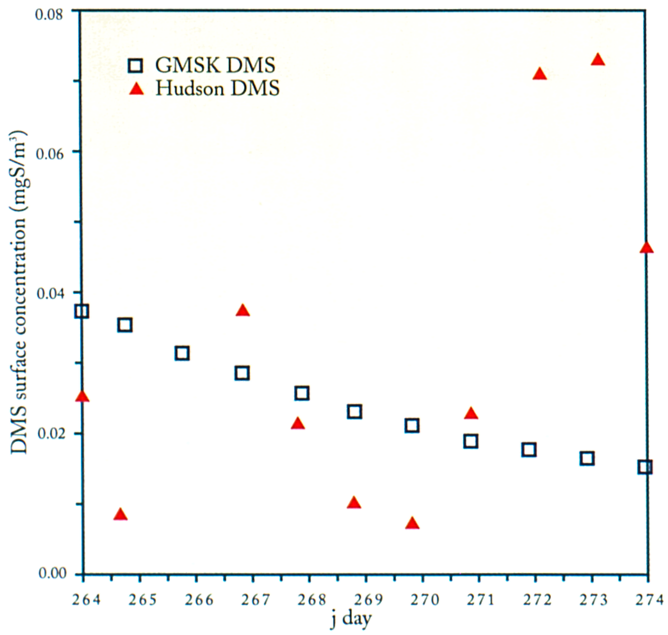


Figure 4.20 b

Parameter	period	temporal resolution
SST	1981 1992	weekly
		monthly
Total cloud cover	1981 1992	monthly
Low cloud coverage	1981 1992	monthly
Medium cloud coverage	1981 1992	monthly
High cloud coverage	1981 1992	monthly

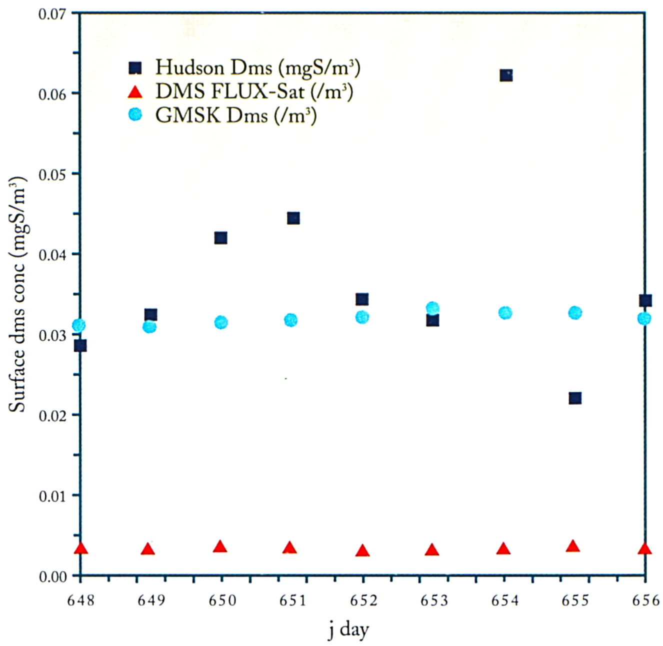


Figure 4.21 b

of chlorophyll at the end of the experiment does not merge from the model output. On the contrary, GMSK model gives better representation of a *"mean"* surface DMS concentration than the DMSFLUX-Sat model (Fig. 4.21b). Such discrepancies are now being analysed. One of the possible reasons is that the models have not been run for a sufficiently long period of time. Also, the chosen starting day, and consequently, the measurements relative to that day, may have a significant effect on the results. A few trial runs confirmed that, given the high variability in the *"in situ"* measurement relative to different days, the choice of the starting day could considerably affect the results.

Although some fairly large variabilities remain at this stage of comparison between both models, these preliminary results are, overall, very encouraging. In view of the new ocean colour sensors that have been recently launched (MOS, Adeos-OCTS) the capability to directly use this data source is particularly useful for future studies on seasonal to annual DMS fluxes over regional to basin scales

The Corsa Project

The CORSA (Cloud and Ocean Remote Sensing around Africa) continued throughout 1996. Focus was again on the development of the data archives and generation of methods for analysing AVHRR Global Area Coverage (GAC) data for the marine environment. The analysis focused on the derivation of so-called Sea Surface Temperature (SST) upwelling index and its relation to physical and biological oceanographic conditions in the 2 major coastal upwelling areas i.e. Northwest Africa and Benguela system. Furthermore, during 1996 cloud detection from AVHRR data has been improved and cloud products have been derived and validated for the period 1982-1992.

Cloud detection and cloud product generation

Cloud detection aims at determining cloud contaminated and cloud free pixels within each individual image. For cloud free areas over the ocean SST is calculated and weekly and monthly composites are generated. Cloud contaminated pixels are used for constructing monthly maps of total cloud cover and classified maps of low, medium and high altitude cloud cover. An example of a monthly image of total cloud cover is shown in Figure 4.22a.

In order to classify the clouds into different heights in the atmosphere a pressure/height profile for tropical atmospheres from LOWTRAN 6 has been adapted, and the cloud top temperature is then used to divide clouds in 3 different classes:

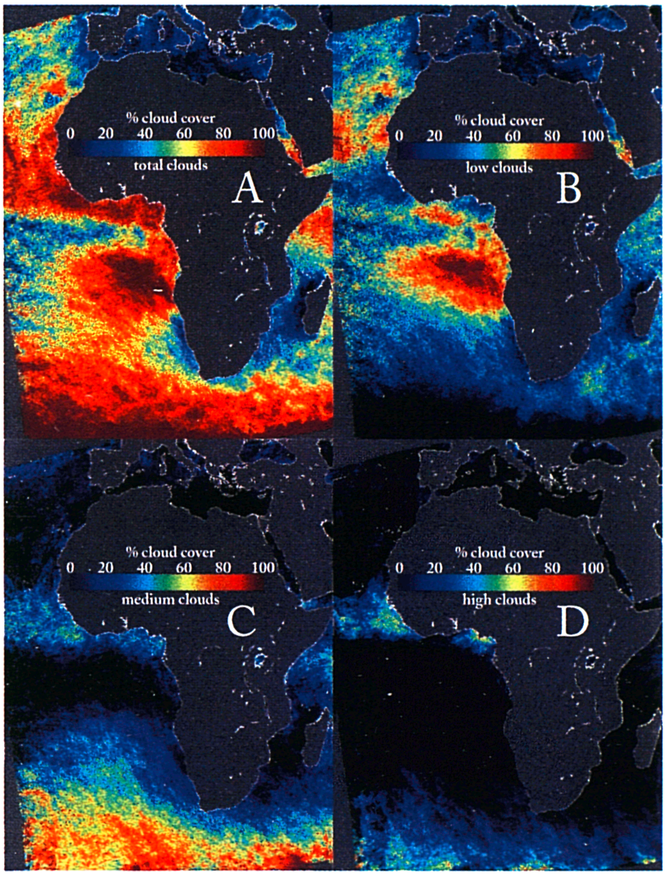


Figure 4.22 : Monthly cloud cover and cloud classification maps for August 1985. A) Total cloud cover B) Low clouds C) Medium clouds D) High clouds.

cloud top temp. T	Pressure P	cloud classification
T<253K	P<400 hPa	high clouds
253K<T<280K	400 hPa<P<700 hPa	medium clouds
280K<T	700 hPa<P	low clouds

An example of cloud classification maps is given in Figure 4.22 B-D.

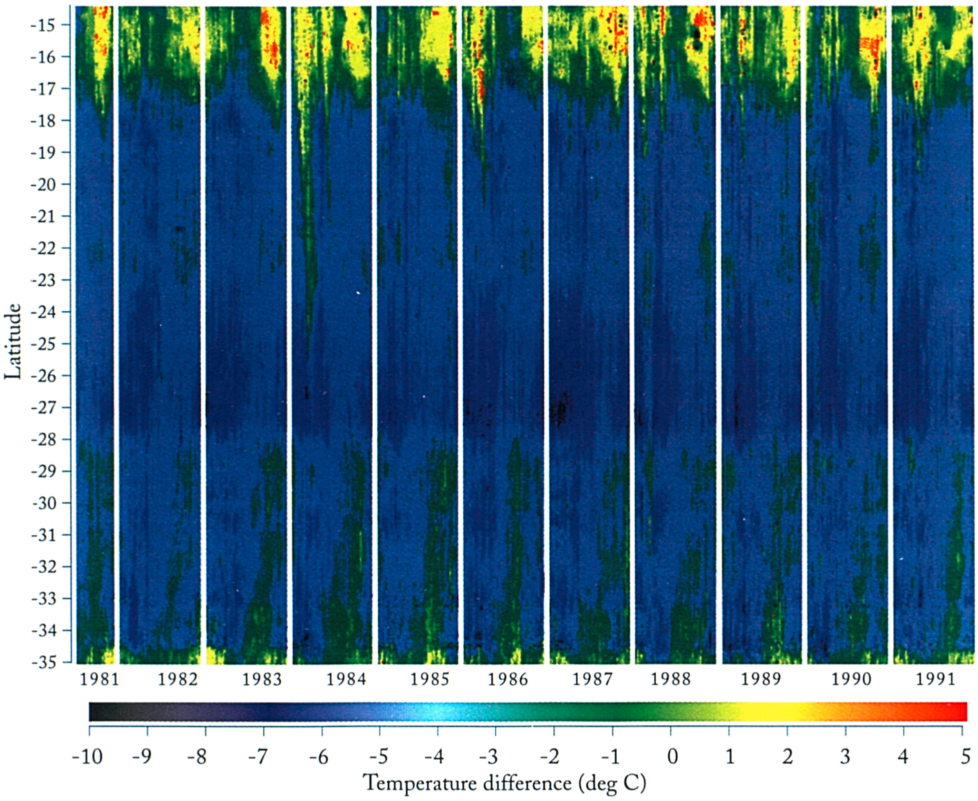


Figure 4.23 : South African SST upwelling index.

Validation

Validation of monthly total cloud cover has been carried out by comparison with data from the International Satellite Cloud Climatology Program (ISCCP). Although the ISCCP cloud cover is only given at a resolution of 2.5° latitude and longitude it is probably the most extensive data set on cloud cover that covers the same time period as the CORSA data. The comparison of monthly cloud cover has been carried out for every month in the period from 1983 to 1991. The CORSA monthly cloud cover when compared to ISCCP shows a bias of 2% and a standard deviation of 8%.

CORSA archive status

By the end of 1996 the derived products (level 3 products) in the CORSA archive comprises:

Time series analysis of SST images

Coastal upwelling has been examined using upwelling indices extracted from the SST images in the CORSA archive. The SST upwelling index is defined as the zonal temperature difference between shelf waters and oceanic water 500 km further offshore. The SST upwelling index is derived from each weekly image for Northwest Africa and South Africa separately. The resulting index for the South African area is shown in Figure 4.23. Missing values from weekly images where no valid data were found for instance due to cloud cover have been linearly interpolated from neighbouring SST values.

A statistical segmentation process has been developed and applied to the SST upwelling index image with the aim of automatically identify the spatial and temporal extent of upwelling cells. The process identifies the 5 main upwelling cells in the Benguela upwelling system, see Figure 4.24. It is immediately seen that coastal upwelling was much reduced for most of 1983 and all of 1984, during which an unusual oceanographic feature known as the Benguela Niño has been recorded.

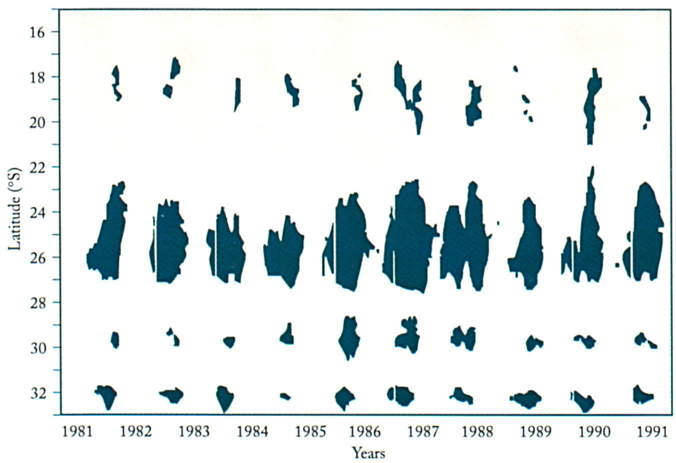


Figure 4.24 : The major upwelling cells identified by image segmentation.

A similar analysis is now carried out for the Northwest African upwelling area in order to determine the possible existence of large scale fluctuations in the Atlantic ocean. The SST index has many applications in physical and biological oceanography. For studies in fisheries science the index has shown to be strongly correlated to recruitment of anchovies in the South African pelagic fisheries. Such a relationship indicates the strong influence of coastal upwelling on the number of anchovy fish that survives the egg and larval stage.

Frontal detection

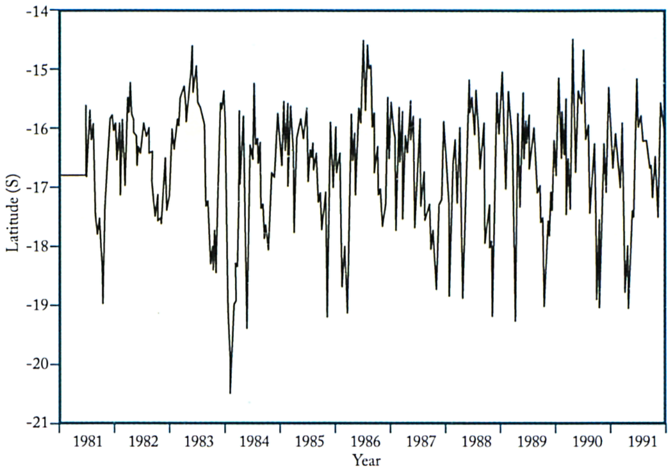


Figure 4.25 : Frontal location fron SST images.

From the analysis of SST upwelling index the presence of strong oceanographic fronts at different localities along the African coast can also be derived. In particular the location of the frontal system between the Angola and the Benguela currents. It has been suggested that the presence of this front may be linked to the success or failure of the pelagic fisheries in Angola and therefore its detection and accurate position has a large impact the fisheries industry. Figure 4.25 shows the result of the detection of the front from SST images. Although the front is seen as a permanent feature, it fluctuates with latitude. Extreme events in the position of the front are easily identifiable from Figure 4.25. Notice the southwards displacement of the front reaching 19° 50' of latitude in early 1984, which coincides with the already recorded warm anomaly, so-called Benguela Niño of the same period.

Perspectives for 1997

A major goal for SAI/ME in 1997 will be to support the European Community with high quality products derived from newly launched sensors and to promote an operational use of satellite data time-series.

- The original OCTOPUS programme (see Annual Rep. 94) will be extended and finalized to include additional instruments (OCTS, MOS) and partners (NASDA, DLR) to ensure the assemblage of an integrated European archive of high resolution optical data.
- The Sea Surface Temperature (SST) and cloud products (GAC data) will be processed for the entire 1993-94 around the African continent. In parallel, a spatial analysis of SST will be conducted to describe the dominant SST fields and anomalies for further application in fisheries.

4.3

Coastal Management and monitoring

Summary of objectives

Identify and define the elements and interfaces needed for a remote sensing oriented Integrated Coastal Zone Management system.

1996 Milestones

Installation and analysis of a detailed local scale GIS for Sicily.

Initiation of a regional scale coastal zone management system for Thailand.

1996 PROGRAMME OF WORK

Introduction

The importance and the role of the coastal zones with respect to economy, ecology and urban settlements is now recognised on both national and international levels, as manifest in projects such as the IGBP's LOICZ (Land-Ocean Interaction in the Coastal Zone) and its European element ELOISE (European Land-Ocean Interaction Studies).

Coastal zones are characterised by high variability in energy and material transfer and transformation processes, changing boundaries, high impact of anthropogenic activities on physical, chemical and bio-geochemical cycles, intensive interaction of the geophysical systems land, ocean and atmosphere and by a large range of relevant time scales (from minutes to seasons).

The coastal environment functions as a buffer zone and interface between the land and open ocean. In order to achieve sustainable development of the coastal areas a substantial effort in Integrated Coastal Zone Management (ICZM) is required.

A remote sensing oriented concept of an ICZM

In response to the existing and emerging needs of the Commission, international/national agencies, governmental and commercial clients, ME began a new initiative in 1996. This focuses on a remote sensing oriented coastal zone management using GIS (Geographical Information Systems) and DSS (Decision Support Systems). The general goal of these activities can be summarised by 'supporting the integration of existing and future know-how and expertise within the ME Unit into ICZM structures and systems and to provide significant added value to collected environmental data'. A general overview of the interactions between the various elements in this concept is shown in Fig. 4.26.

The know-how and expertise concerned are mainly linked to the development and application of algorithms for processing marine remote sensing information, the preparation of time series, the statistical interpretation, the simulation of marine/coastal processes and the application of data assimilation techniques.

In 1996, activity within ME mainly concerned computing issues (e.g. data formats, data exchange and transfer rates, distributed data bases and processing, integration of interactive simulation tools) of the appropriate GIS, DSS and analysis techniques to be used.

The work related to ICZM was guided by consideration of the general aims of the CEO (Centre for Earth Observation - see chapter 7) to achieve an effective data and information access and interpretation supporting coastal zone research, monitoring and management.

Specific objectives are:

- Development of a concept for a user-driven and user-oriented data and information system (DIS) based upon existing elements and activities and allowing for an advanced integration and linkage of remote information systems, databases and tools;
- Application, where possible/available of agreed standards for data and information exchange;
- Considering the use and implementation of robust hard/software tools which generate a widespread use and acceptable maintenance effort.

This work related to ICZM is supported by funding from CEO in the frame of the CEO-Application Project 'Decision Support for Integrated Coastal Zone Management (DESIMA)'. The Project started officially with the kick-off meeting at the end of October 1996 together with the DESIMA Advisory Board which is made up of representatives from relevant Commission Services and from Member States institutions.
During this meeting the proposed approach for the DIS was discussed and approved by the Board. Practical Project work comprised the elaboration of a Project work plan and the identification and selection of required external expertise (in particular GIS) needed for the Project's initialisation.

The generic concept to be developed within DESIMA will be applied to different projects and activities on both JRC and Commission levels. A first application of the DESIMA concept will be made in the frame of an EU-Thailand co-operation for a Feasibility Study on 'Sea Rehabilitation/Coastal Areas Management'. The Project started with a joint EU-Thai workshop (29 November - 3 December, 1996) at JRC during which a work plan and

CEO Project - DSS *(Decision Supporting System)* for Coastal Areas/Concept

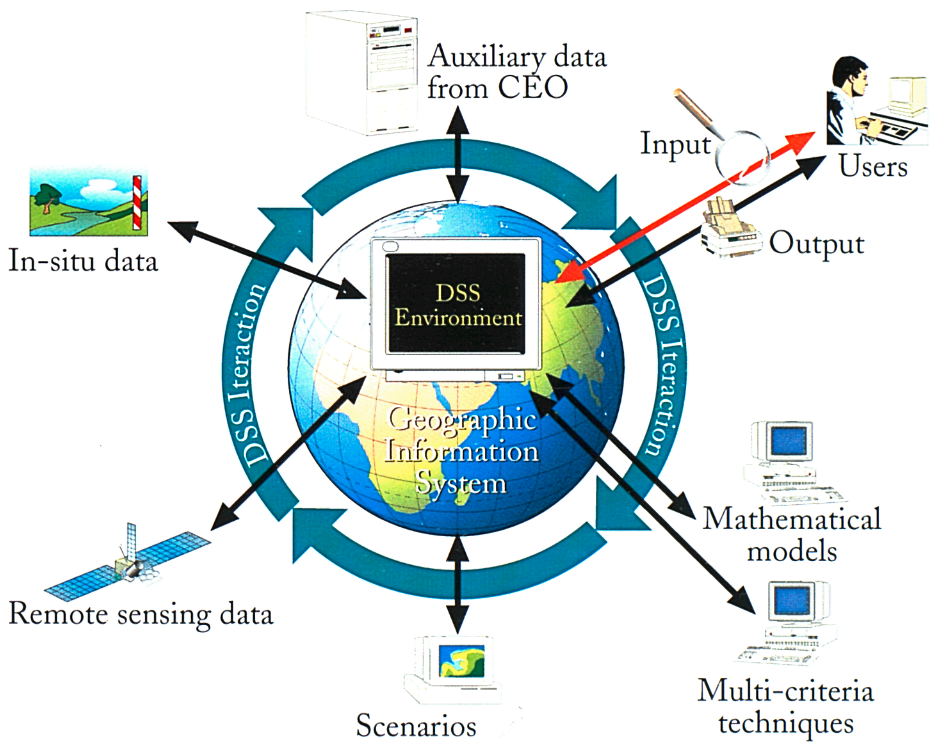


Figure 4.26 : Concept of a GIS based Decision Supporting System for integrated Enviromental Management.

objectives were confirmed. The user-oriented approach and the planned active cooperation with the Thai institutions working in the areas of remote sensing, geographical information systems and coastal zone management was emphasised, and this project will be a focus for the ME ICZM activities in the 1997.

Integrated marine and coastal GIS for the Sicilian region

Building on the experimental GIS for the Island of Sicily, developed in 1995, a system combining satellite image processing elements, spatial data management and data base manipulation has been developed. This integrates conventional cartographic data, with remotely sensed data from a range of instruments, such as the CZCS, the AVHRR and the Thematic Mapper (TM). In 1995 development largely addressed regional scale issues; from which DESIMA undoubtedly profited in 1996. Recognising this "test bed" role for the Sicily work, in addition to its direct value, the Unit tuned the system to a local scale focus for 1996.

Local scale

At the local scale, the work concentrated on the Simeto river basin, and its coastal section on the Gulf of Catania, as outlined in Figure 4.27. Parameters describing essential coastal water constituents and vegetation were derived from TM data (1985 and 1994). The ancillary data set integrated with the high-resolution images includes both physical and biological components of the local coastal environment (geographic, geological, geomorphologic, sedimentary and vegetation outlines).

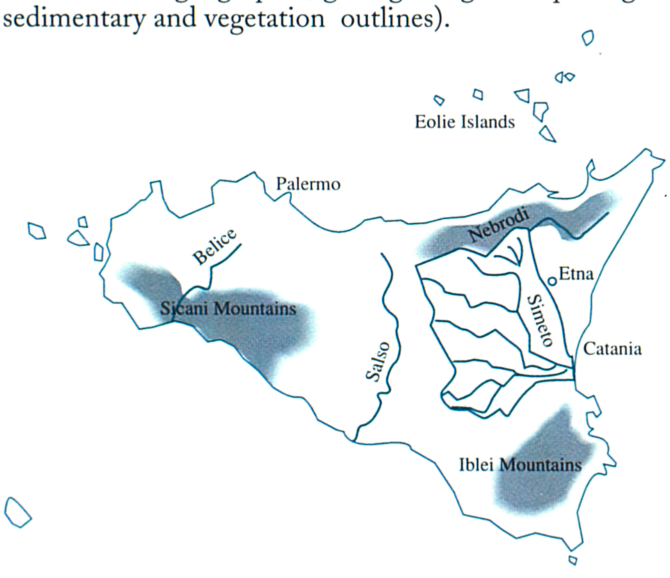


Figure 4.27

Geographic outline

The coastal zone of the Simeto basin, south of Catania, includes both a protected area and tourist areas. The limits of the area of interest for the present study were selected on the basis of information available in the literature. The area has a width of 14 km (8 km landward and 6 km seaward) and is 23 km long. The geographical boundaries of the Simeto basin are determined by the Etna mountain, to the north, the Ebrodi mountains, to the west, and the Iblei mountains, to the south. The coast type is essentially a beach platform.

Climate

The Simeto basin is the largest on the island, with a total area of 4200 km^2. The river originates from the Nebrodi mountains, at the confluence of the streams Cuto', Martello and Saracena. Its main tributaries are the streams Serravalle, Salso, Dittiano and the Gornalunga river. The outflow of the Simeto river used to be around 18 m^3 sec^{-1}, but it has been reduced in recent years by the presence of four dams (Ancipa, Pozzilo, Ogliastro, and Nicoletti), as well as by uncontrolled quarrying and water collection from the various fluvial branches, which causes parts of the river to dry up in summer. Wetlands, representing an important ecosystem for rare species of plants and animals, are also present in the basin.

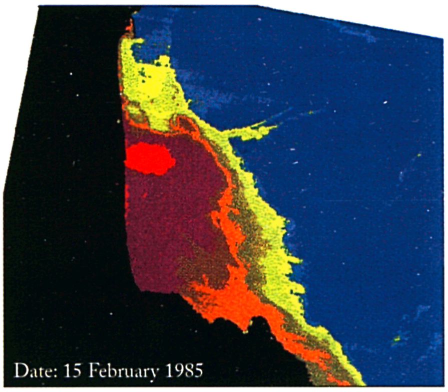
Data collection

The complex coastal ecosystem is influenced by many factors: climate, hydrology, marine characteristics, sedimentological outline, vegetation cover and anthropic influence. For this reason a wide range of data were collected for integration in the local area GIS (i.e., topographic maps of the area, aerial photographs, daily and monthly precipitation, isobath map, vegetation map,...). The coordinates of the centre of the Landsat Thematic Mapper images are 37.20 N and 15.30 E; the image sequence covers two phenological cycles, in 1985 (15 February, 22 May, 10 August) and in 1994 (12 March and 3 August).

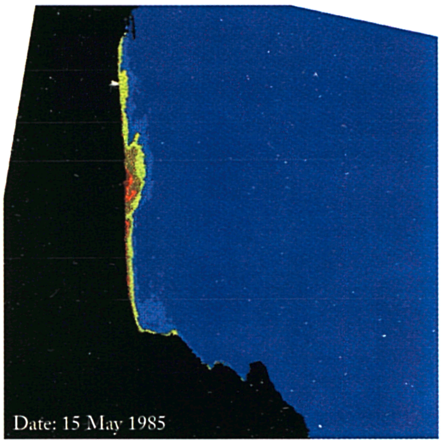
Suspended sediments, just discharged from rivers or channelled by longshore currents, can float over clear water as thin (0.5-1.0 m) layers. The application of two sediment retrieval algorithms, operating on TM channel 2 and 3, can give information on the thickness of the turbid layer, provided that the turbidity is not too high. The possibility of discrimination derives from the fact that the water is more absorbing at the wavelength of TM channel 3 than at that of TM channel 2: it follows that the reflectance in channel 2 (R2) carries information on deeper water than with the reflectance in channel 3 (R3). In the presence of a layer of turbid water floating over clearer water the retrieval algorithm using R2 data yields lower suspended sediment concentration than the algorithm using R3 data.

From the ratio R3/R2 one can get (semi-quantitative) information on the thickness of the (upper) turbid layer, while R3 contibutes to a good estimate of the actual suspended sediment concentration in the same layer. Such evaluations were applied to the TM images covering the area of the Simeto river plume.

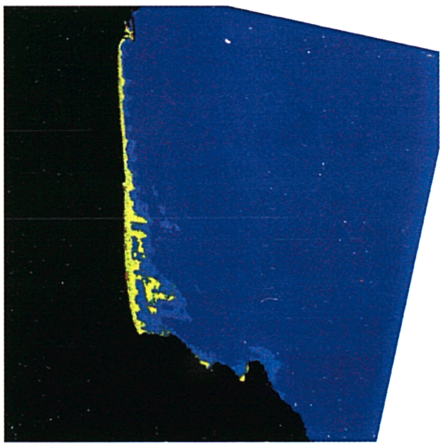
Some results of the TM image analysis are reported in Figure 4.28 (a,b,c), which shows the main variations of the Simeto river plume during 1985. As expected, the maximum plume extension corresponds to the maximum of precipitation (winter season).



Simeto river mouth: suspended sediment concentration from TM channel 2 (560nm)



Simeto river mouth: suspended sediment concentration from TM channel 2 (560nm)



Simeto river mouth: suspended sediment concentration from TM channel 2 (560nm)

Figure 4.28

GIS integration

The Coastal Zone Digital Model (CZDM), a three dimensional model of the studied area, was generated linking coastal topography and bathymetry, obtained digitising the isobaths up to 2000 meters of depth. The coastline was taken from a nautical map. All different landscape elements (natural vegetation, cultivated areas, roads, canals, rivers, lakes) were digitised from the vegetation map of the Simeto natural park. The different coverages were directly obtained in a real-word co-ordinates system, because the vegetation map was geo-referenced. The coastlines have been digitised (and converted to the same co-ordinate system and geographic projection) from topographic maps and aerial photographs representing the area of study in four different periods: 1866-68, 1924-26, 1967, 1987.

Figure 4.29 shows the CZDM introduced into the GIS. The comparison between the different coastlines (1866-68, 1924-26, 1967) is shown in Figure 4.30. The overlay shows changes at the mouth of the Simeto river, a shift of 2 km to the south from 1868 to 1967, and a withdrawal of about 80 metres from 1926 to 1967. Interestingly, an even bigger coastline erosion was measured from field work data, in particular near of the mouth of Simeto. These results agree with the general coastal retreat in the area due to reduced river discharges linked to damming, uncontrolled carrying and water use in general.

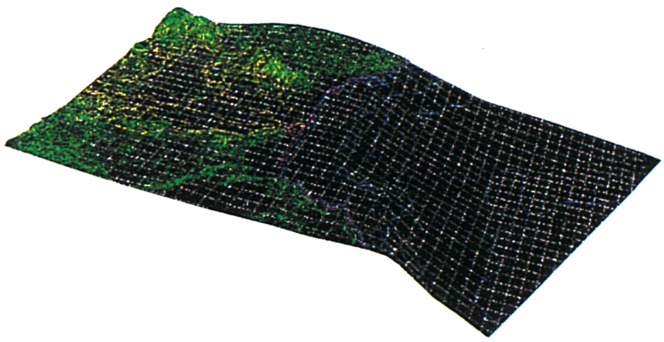


Figure 4.29 : Simeto basin coastal area, Coastal Zone Model.

The adoption of a dual, regional and local, GIS structure has allowed to monitor phenomena which interest entire basins, but also to zoom in and observe small scale phenomena taking place within such basins. Examples of the synergistic use of the different data sets, integrated in the GIS at various space/time scales, include assessing the impact of runoff from hydrological basins on the marine ecosystem, sediment transport and coastal evolution, vegetation cover.

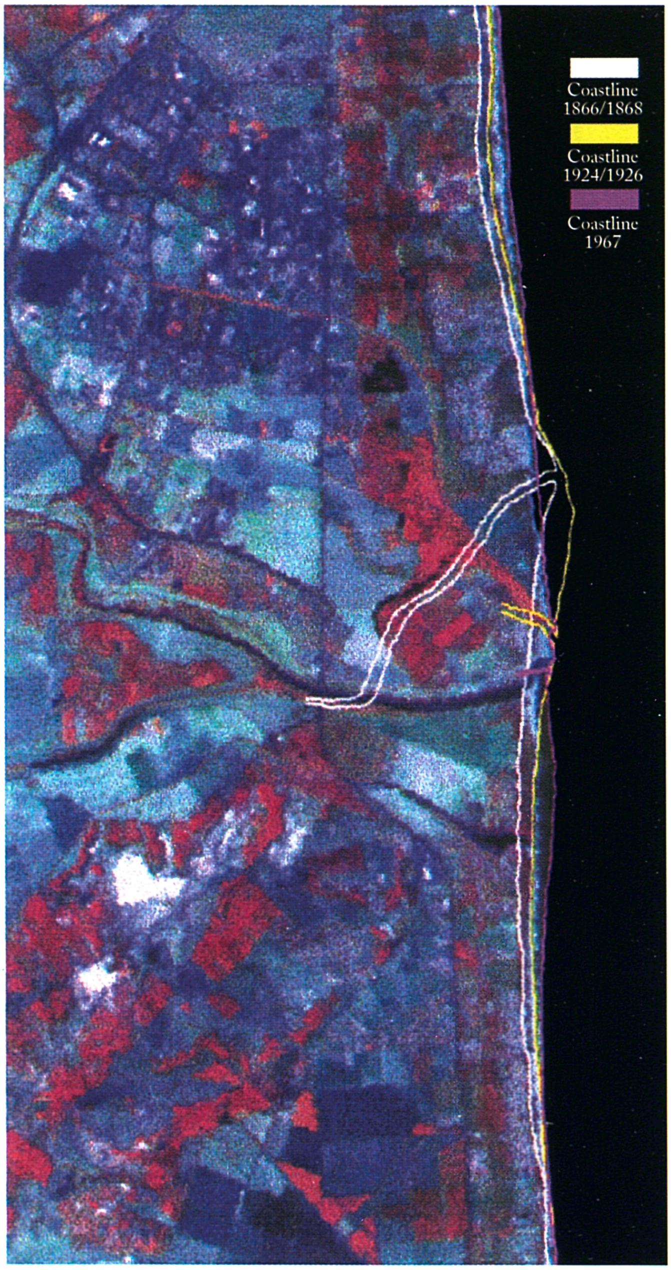


Figure 4.30 : Coastal evolution 1886 to 1987.

Perspectives for 1997

The ME Unit sees coastal zone studies as an important focus for the coming year. Much of this effort will be aimed at the Thai feasibility study. This will define the concept for a Decision Support System (DSS) for ICZM for Thai tropical coastal ecosystems using GIS technologies. The planned project work is divided into four main work-packages:

1.Inception phase:
- assessment of the present ecological, environmental and socio-economic situation in Thai coastal zones, and expected future developments (supported by a EU-Thai workshop);
- detailed work plan and study issues definition;
- development of a cooperation plan with Thai partners.

2.Information assessment:
- user's assessment;
- data sources assessment;
- existing projects and activities on Thai coastal zones.

3.Analysis and system configuration:
- definition of user requirements (supported by a joint EU-Thai workshop in Thailand);
- definition of functional specifications;
- definition of technical specifications;
- human resources development.

4.Implementation plan
- joint EU-Thai evaluation workshop in Thailand
- implementation plan 1997-2001.

4.4

Remote sensing data assimilation

Summary of objectives

- Development and application of a data assimilation tool for assimilating Sea Surface Temperature and altimeter data
- Investigation of the near surface turbulence characteristics, specifically concerning the relationship between interface and bulk processes
- Improvement of available tools for assimilating remote sensing observations.

1996 PROGRAMME OF WORK

1996 Milestones

- First application of the data assimilation tool to an Atlantic upwelling window
- First measuring campaign in the frame of the MAST-III ELOISE project PHASE
- Start of 2 further MAST-III projects (MATER, BASYS) and the ENV project NEUROSAT

Introduction

1996 saw both progress and concrete results, in the light of the objectives stated above. Concerning the development of a data assimilation tool, a prototype version was applied for the first time to a real situation. This tool is essential for our participation to the ENVIRONMENT AND CLIMATE project NEUROSAT, which started towards the end of 1996.

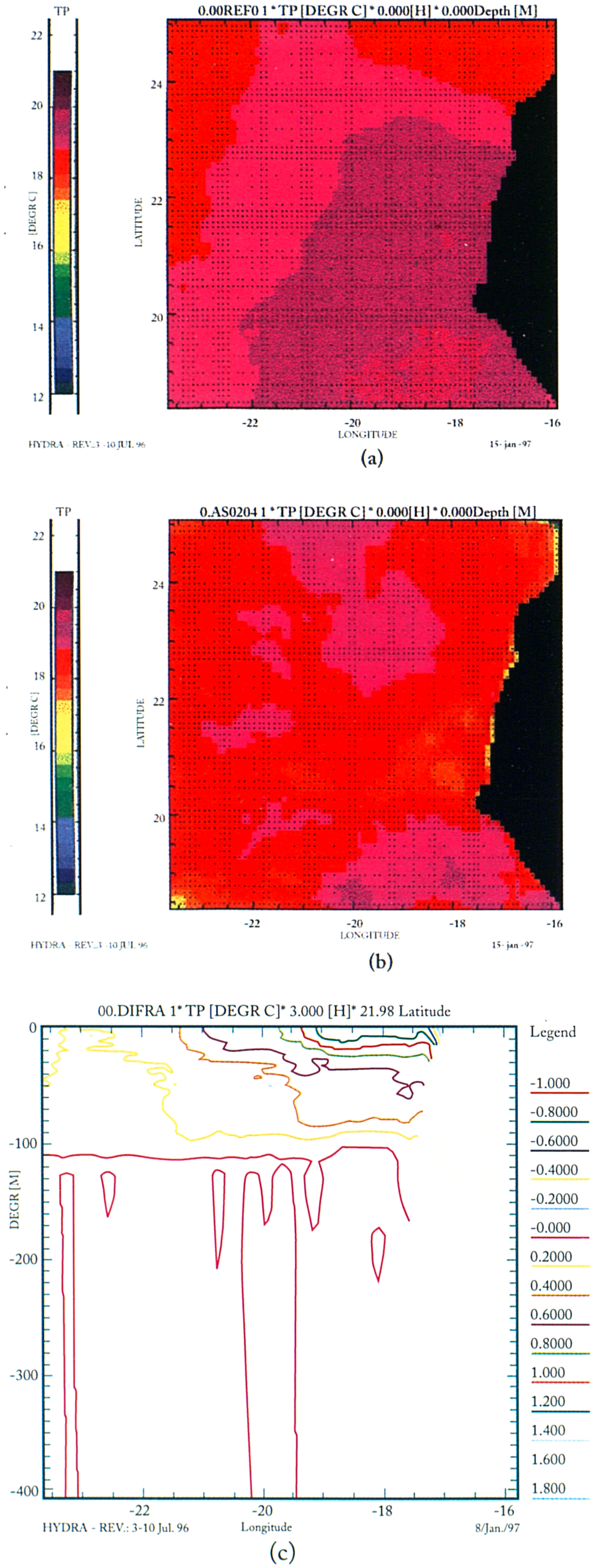


Figure 4.31 : (a) first guess of the initial condition (b) Initial condition as result of 4D Variational Data Assimilation, (c) Difference between calculated temperature without and with DA in a cross section.

Application of the data assimilation tool ISPRAMIX to an Atlantic upwelling window

The application starts with a known initial condition, which has been obtained by a preliminary simulation of the Atlantic circulation with the model ISPRAMIX.

Fig. 4.31a shows the sea surface temperature in the Cap Blanc study site obtained using ISPRAMIX for March 2, 1982. The 3D initial temperature field serves as a first guess for starting the iterative assimilation system. It is perhaps important to recall that 4D variational data assimilation system is based on a minimisation procedure to minimise the misfit between the model simulation and remote sensing observations. The objective function - the so-called cost function - is obtained by a forward in time computation (direct model ISPRAMIX), and its gradient with respect to the minimisation variable is computed by a backward in time computation (adjoint model ISPRAMIX). The minimisation variable chosen here is the temperature initial condition. The result of the procedure is a new temperature initial condition which minimises the misfit between the model results and the remote sensing observations.

The parameters determining the size of the problem are the following. The horizontal model step is 0,1° in longitude and latitude, the vertical step consists of 38 levels, the corresponding total number of grid points is 155.000. The horizontal grid coincides with the remote sensing data evaluation grid, providing 4 data pixels per model grid element. The chosen assimilation period is 3 days, March 2 to 4, 1982, which - using a computational time step of 2 hours - means a total number of 36 time steps. Since the time backward application of the adjoint model requires the knowledge of the time forward model computation, all 3D field variables of the forward computation have to be kept in the computer working memory for 36 time steps, which leads for the present application to an internal memory requirement of about 1 Gigabyte. The results presented here were obtained after 20 iteration cycles requiring 30 CPU hours on the SAI CRAY parallel computer J916 .

Figs 4.32 a,b,c, show the SST observations available once every day at about 2 pm. The single pixels which may be identified in these figures represent the model grid elements, i.e. the corresponding temperature value is the average of 4 remote sensing pixel values at most. The observations represent a clearly different temperature structure as suggested by the first guess initial condition in Fig. 4.31a. The application of the assimilation system leads to a new initial condition for the temperature field as shown in Figs. 4.31b and c. Fig. 4.31b shows a cold structure superimposed on the first guess field. The system has adapted the temperature field in depth as well as shown in the 22° latitude section, Fig. 4.31c, which suggests an upwelling type origin of the cold structure. (Since the figure shows the difference ($T_{first\ guess}$- T_{final}), the isolines with positive levels indicate a temperature decrease).

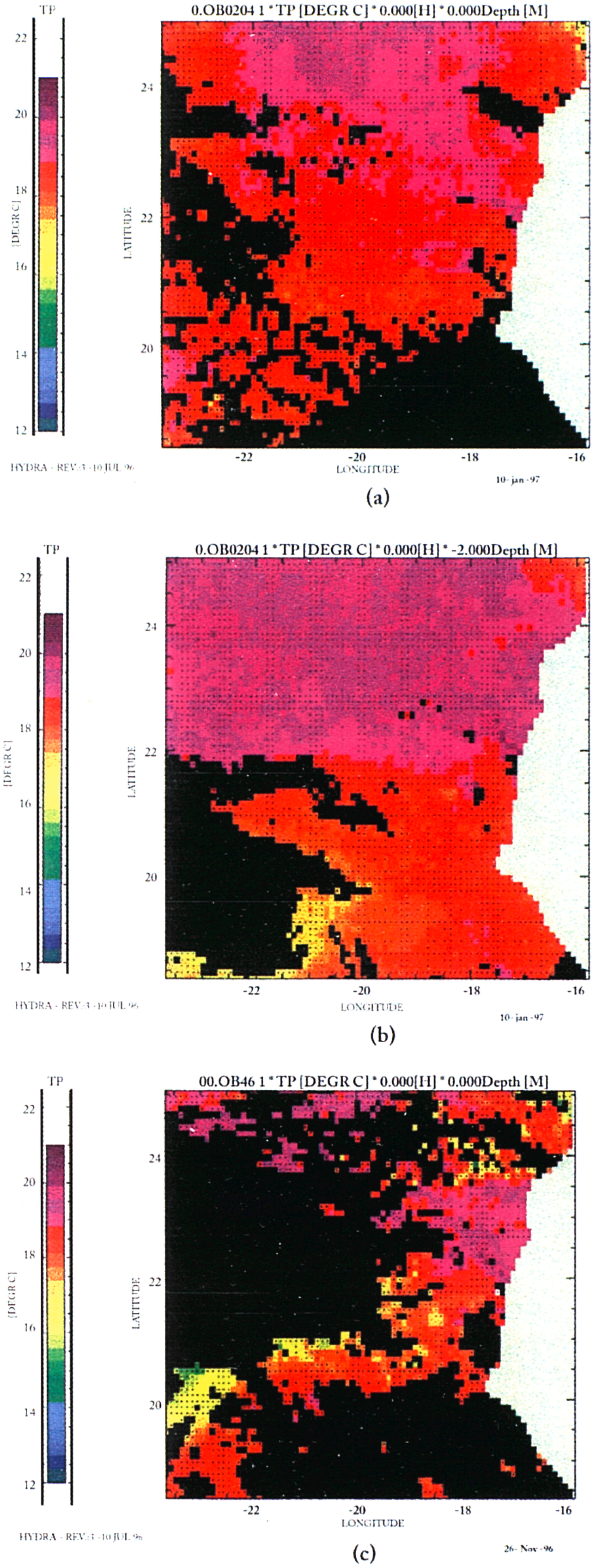


Figure 4.32 : derived Sea Surface Temperature data: 2,3, and 4 March 1982 (a,b and c).

In Fig. 4.33 a,b,c, the final computed sea surface temperatures at 2 pm on March 2, 3 and 4 are confronted with the corresponding observations. It is seen that the model interpretation of the observations is a kind of meandering cold structure. However, while the intensity of the cold structure is increasing with time in the observations, it is decreasing in the simulations. This is due to the fact that the assimilation procedure applied here may only change the initial condition, and it obviously does it in a way that the phenomena are reproduced in the average of the 3 days. There is still a need for improving this approach, maybe by overlapping consecutive assimilation periods.

What are the consequences of the cold structure for the window physics? this may be seen from Fig. 4.34, where for March 2 the differences between parameters obtained without and with data assimilation are represented. Part (a) shows the temperature difference, ranging in the centre of the structure up to 3 K. Part (b) shows a strongly correlated signal in the water elevation. The cold structure superimposes on the existing water elevation field a "low" of up to 2 cm. This "low" generates a cyclonic circulation component (part c) coupled with a "twin" anticyclonic circulation component.
This example demonstrates impressively the potential of using remotely sensed SST data for reconstructing eddy like flow structures in ocean circulation -here an eddy like flow- in case the model results did not show them. This may be of great importance for simulating correctly transport in upwelling areas with high fish variability.

Activities related to the investigation of the near surface turbulence characteristics

In 1996 the EU MAST-III project PHASE (MAS3-CT96-0053, Physical Forcing and Biogeochemical Fluxes in Shallow Coastal Ecosystems) was launched. As part of the SAI contribution measurements of kinetic energy dissipation rate were performed (in collaboration with ME-GmbH, NERI, NIOO) in the Netherlands.

During the core measurement phase of the Oosterschelde workshop campaign (June 20th until June 28th 1996) quasi continuous measurements of turbulent dissipation rates and other water properties, using two MST profilers were performed. One profiler worked in the uprising mode, released from a bottom mounted underwater winch, the second worked in the falling mode released from the vessel *"Luctor"* of the NIOO. The simultaneous use of two profilers was not foreseen in the contract, but is the only way to achieve a complete temporal/spatial coverage of the water column. Altogether 600 profiles from the falling probe and 370 from the rising probe were collected. A preliminary data elaboration and analysis was performed in 1996.

Preparing measures were undertaken for ensuring the successful SAI participation in the EU MAST-III project BASYS (MAS3-CT96-0058, Baltic Sea System Study), which concerns especially the planning of the measurement campaign and the adaptation of the measuring technique.

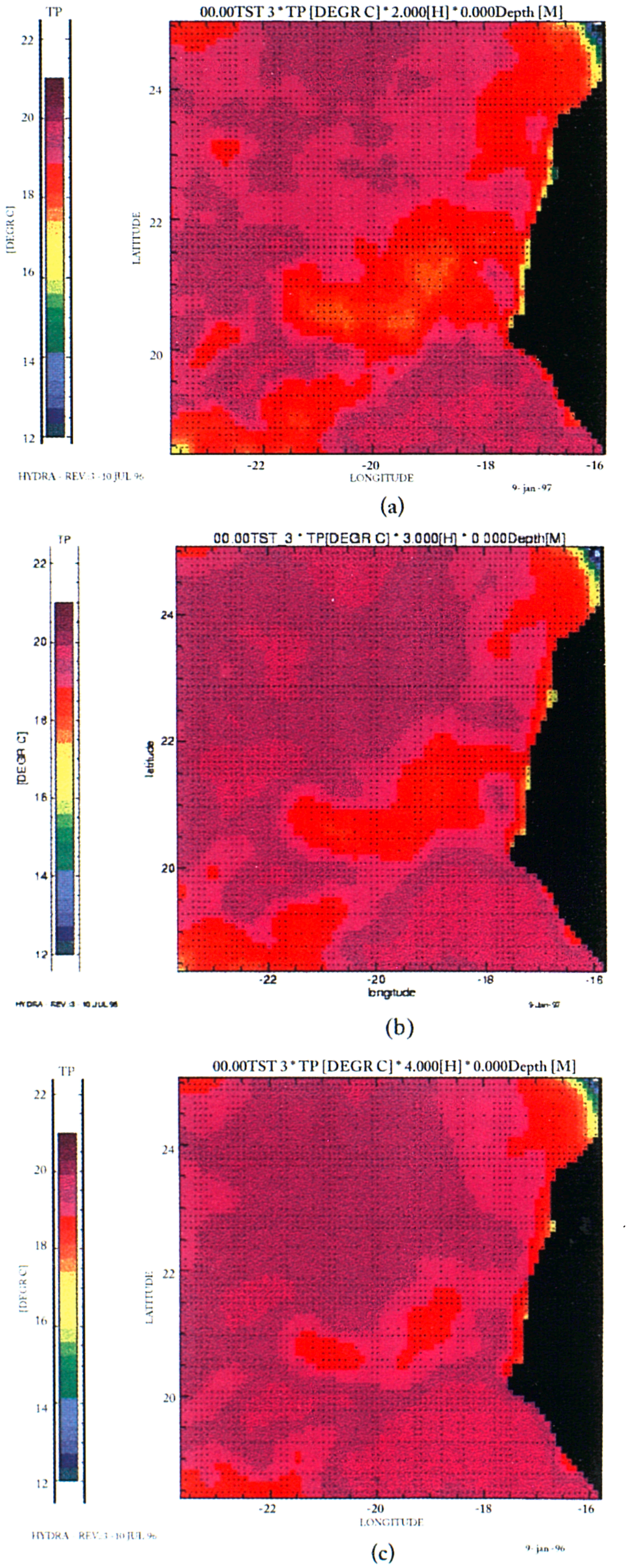


Figure 4.33 : retrieved SST data 2,3 and 4 march 1982. (a,b and c), obtained by application of 4D Variational Data Assimilation.

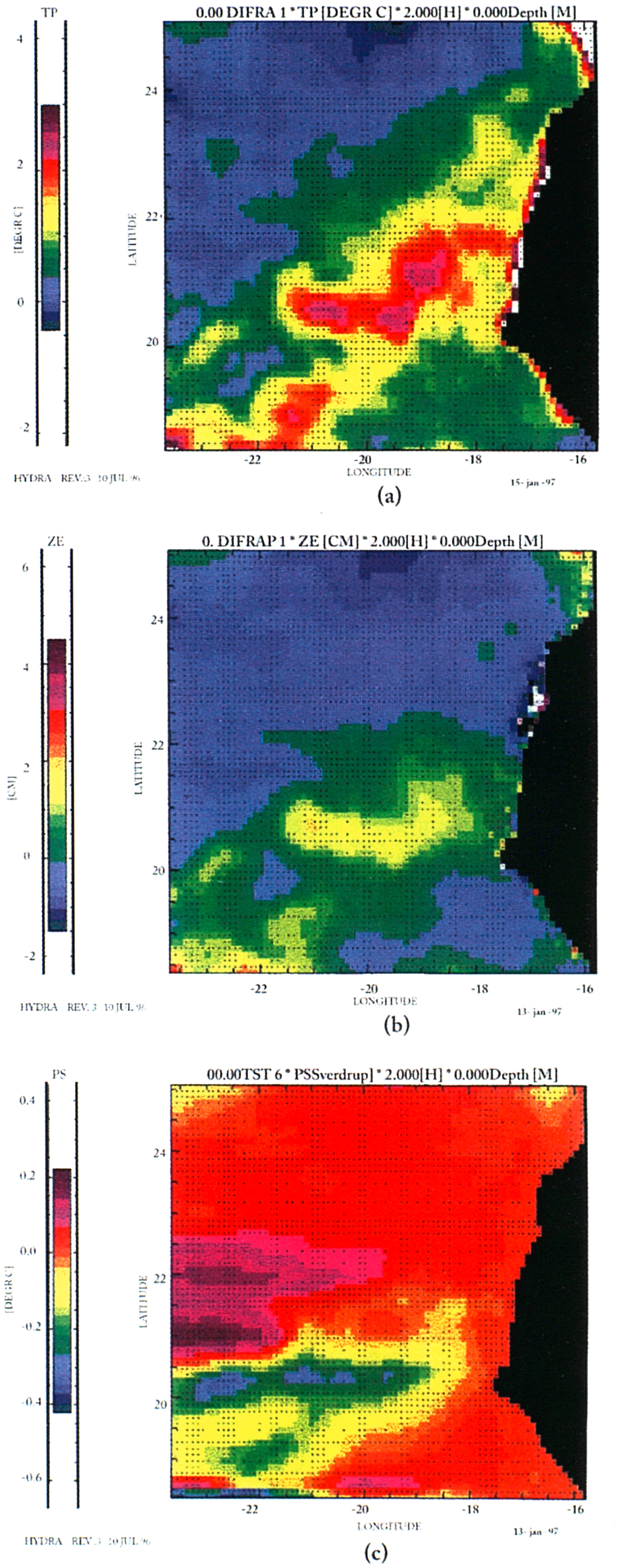


Figure 4.34 : retrieved SST data 2,3 and 4 march 1982. (a,b and c), obtained by application of 4D Variational Data Assimilation.

The EUREKA/EUROMAR project MICSOS (EU1246) was continued successful in 1996. In the framework of the MICSOS project two measurement campaigns were performed, that demonstrated the operational functioning of the developed prototype profiler.

In March 1996 an extensive measurement campaign was performed in Lake Neuchatel, Switzerland. Participating institutions were besides the SAI, the Swiss Federal Institute for Environmental Science and Technology (EAWAG) Switzerland, the National Environmental Research Institute (NERI) Denmark and the ME Meerestechnik-Elektronik GmbH Germany. A total of more then 1100 microstructure profiles were collected with the SAI profiler. Additionally a complete set of meteorological data, current meter data, surface wave data and thermistor string data were gathered. The basic data evaluation was finished in 1996 and a technical report is in preparation. The surface layer dynamics during about 11 measurement days is shown in Fig. 4.35. The presented fields of temperature and turbulent kinetic energy dissipation, demonstrate the reaction of the near surface layer to wind and buoyancy forcing. In July 1996 a further measurement campaign was conducted in the Northern Baltic Sea (Gulf of Finland). Participants were from the Finnish Institute of Marine Research (FIMR) Finland, the HYDROMOD GbR Germany, the Estonian Marine Institute (EMI) Estonia, the University of North Carolina USA and from other institutions. This was also part of the international research project on *"Hydrodynamical control of cyanobacterial blooms in the Baltic Sea: the effect of small-scale turbulence"*. The extreme temperature stratification found during these measurements led to an further improvement of the MICSOS shear sensor.

Perspectives for 1997

In 1997, data assimilation will complete and fully document the first application. A new focus will be the SAI contribution to the ENV project NEUROSAT (which had a delayed start just before the end of 1996). This contribution will include the assimilation of R.S. altimeter data. In addition, a new application will be made which will deal with a South African upwelling window with high fishery interest. The investigation of the near surface turbulence characteristics will centre on the SAI contributions for 3 MAST projects: PHASE, BASYS and MATER. MATER - The Mediterranean Targeted Project - expects as SAI's contribution to provide and implement in a community circulation model a turbulence model validated by the SAI measuring campaigns. The same model will be implemented into the ISPRAMIX assimilation system.

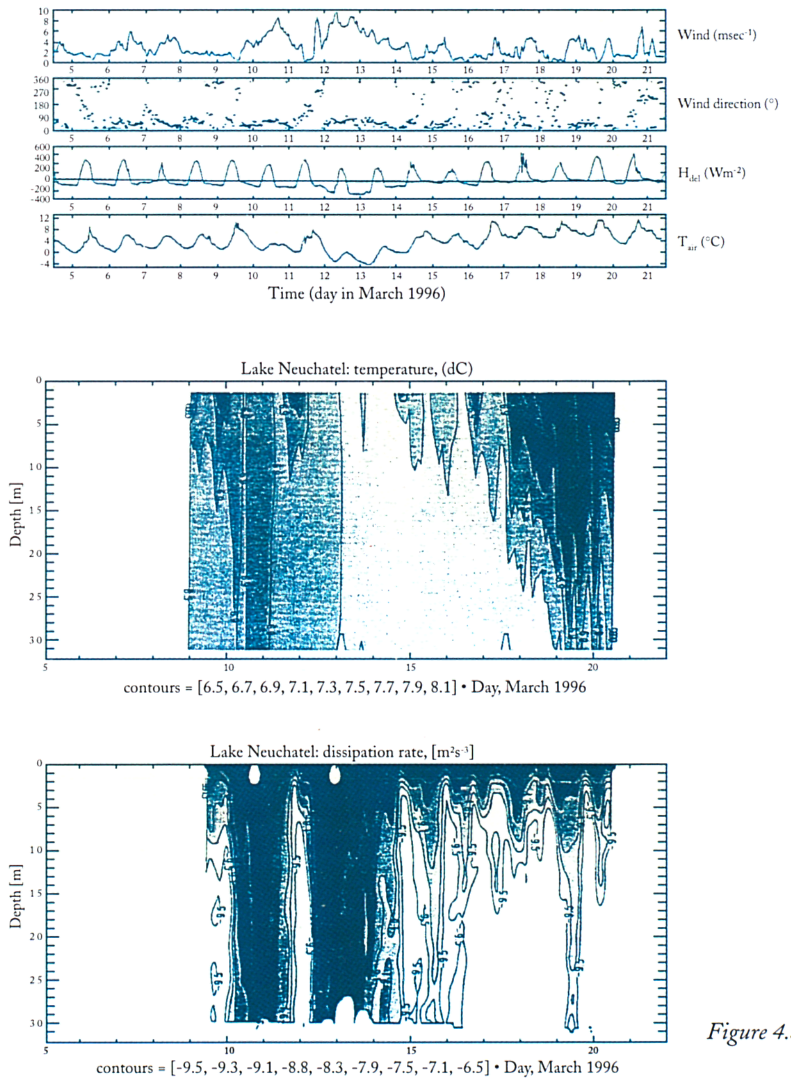


Figure 4.35

Monitoring Tropical Vegetation

During 1996, the MTV Unit developed a series of techniques and approaches to the monitoring of the Earth's vegetation cover. A few points are of particular relevance to the evolution of earth observing techniques. First, it is worth noting that progress made in the TREES and FIRE Projects are leading the laboratory closer to proposing operational systems which could guarantee with a growing level of reliablity the provision of information on the state and conditions of the vegetation cover on the global scale.

The exercise carried out in the pan-tropical TREES analysis and the development of the global fire product further provide strong indications that research is now in better position to propose acceptable solutions to the monitoring of complex land surface conditions. The last year of activity has also demonstrated that microwave data (from ERS-1/2 and JERS-1) can significantly contribute to the objectives of global monitoring of ecosystems. The amount of data and the complexity of the processing involved in the production of large area radar mosaics at a medium to high resolution are such that until recently such analyses could not be realistically considered. The work of MTV scientists has contributed to the demonstration that several instruments can be meaningfully integrated in order to enhance their contribution to global and continental monitoring objectives.

The MTV has conducted a growing share of its research in close collaboration with international programmes. The close association with a wide range of laboratories and Space Agencies in Europe and abroad has forced a refocusing of priorities in the research agenda. This has also opened new investigations leading to better linkages between the local, regional and global analyses. The case of the FIRE project can be cited here for its innovative activities in the field of local reception of satellite data as well as in the design and implementation of a satellite-derived global fire product. The TREES project has encountered a similar challenge in its attempt to open its data sets and results for exchange and validation by a broad community of users, from the global change scientists to local forestry services in some countries. In opening such lines of activities the MTV Unit hopes to contribute to the resolution of persisting difficulties associated with the multiscale nature of global monitoring.

Global monitoring of vegetation being by definition geographically widespread there is a need to integrate data from different sources. There is a growing number of sensors which, given constant progresses in our capability to handle large data sets, must urgently be considered for continental and global monitoring. As the present report shows the MTV Unit is being engaged in a wide examination of panoply of earth observation instruments. A participation to the VEGETATION preparatory programme has been established and dedicated research has been conducted. Specific contributions to the preparation of other European and non-European instruments have also been provided. The Unit's perspective on a series of microwave instruments has expanded. In the course of such work it has become clear that maintaining a certain level of involvement (or at the least of awareness) in the increasing number of earth observation programmes being conducted or prepared is critical for the future of global resource and environment monitoring.

Coping with large earth observation and ancillary data sets and making such data broadly available for analysis is fast becoming a major activity in its own right. Current efforts in the MTV Unit are geared to cope with the rapid expansion of the requirements associated with data and information. Numerous activities carried out under the various names of MTV-GIS, TFIS (Tropical Forest Information System) and VFIS (Vegetation Fire Information System) are detailed in this report. Concerns for the users requirements in terms of access to global satellite products are reflected in the design, in collaboration with industry, of automatic catalogue interrogation systems and interactive search procedures.

The development of global vegetation and environment monitoring techniques requires investments in facilities and expertise which are now well establised in MTV. The Unit is now in a position to expand its analyses to new earth observation instruments, to ecosystems little considered sofar (i.e boreal forests, dry subtropical forests) and to environmental parameters which can now be approached using improved analytical techniques.

5.1

Monitoring of biomass burning The Fire in global Resource and Environmental monitoring project (F.I.R.E.)

Summary of Objectives

- To develop remote sensing based methods for the monitoring of vegetation fires,
- To apply such methods to document temporal and spatial distribution of fires at regional, continental and global scales,
- To analyse such distributions patterns in relation to land cover - land use dynamics with particular interest to the savanna-forest transition zone of the tropical belt, in relation to atmospheric chemistry, climate change and environmental management.

1996 Milestones

June: A set of standardised biomass burning products at various scales from local to global is implemented and made available to the international scientific community
Production of the first Continental Atlas of Fire Activity for Africa for a 5 years period: 1984 to 1989

October: Second SAI-IGBP-ESA workshop on Global Fire Monitoring in Toulouse

November: Joint intensive EXPRESSO field experiment, with the Natural Resources Institute (NRI, UK), the National Centre for Atmospheric Research (NCAR, USA) and the Institut des Sciences de l'Univers (INSU, F), in Central Africa, to study the impacts of biomass burning on tropospheric chemistry.

1996 PROGRAMME OF WORK

Introduction

In 1996 the **FIRE** project activities have been pursued in relation to:

- The documentation of biomass burning patterns: The work done in 1996 has focused on (i) the analysis of the spatial and temporal pattern of fire activity at a regional scale in Central Africa using AVHRR 1 km resolution data, (ii) the continuation of fire mapping at global level from the IGBP-DIS Global 1 km AVHRR data set, (iii) the analysis of the impact of the spatio-temporal distribution of fires on the chemical properties of the troposphere in tropical Africa.
- The development of tools and methodologies has concerned three main aspects:

  (i) A comparative evaluation of NOAA/AVHRR vegetation indices for burned surface detection and mapping
  (ii) The development of a software package for the Pre-Processing and processing of NOAA-AVHRR images acquired with a portable receiving station.
  (iii) The improvement of the prototype processing chain required for the production of the Global Fire Product.

- A scientific contribution to the IGBP core projects IGAC and DIS
- The analysis of the relationships between patterns of fire distribution and the degree of fragmentation of the tropical forest, in the framework of the TREES-II project.

Main results

Monitoring vegetation fires

At a global level, the Global Fire Product activity has been further strengthened by (i) improving the accuracy of the global fire maps and by (ii)continuing the systematic processing of the IGBP-DIS Global data set available: 24 weeks (from April 1992 to March 1993) of daily global data have been analysed to produce maps of fire distribution. Figure 5.1 shows the temporal dynamics of observed burning as a function of latitude. A set of standardised biomass burning products has been implemented at different scales and made available to the external user community.

At the continental level in Africa, monthly and 10-day maps of the distribution of active fires from 1984 to 1989 have been analysed to derive the seasonality of biomass burning for the African continent, within 1o x 1o grid cells, and to produce the first Continental Atlas of Fire Activity over such a long period of time.

At the regional level in Central Africa the fire monitoring programme, initiated in December 1993 for this region, was completed by systematic fire monitoring during 1996. A 3 year data set (1994 to 1996) is now available to derive

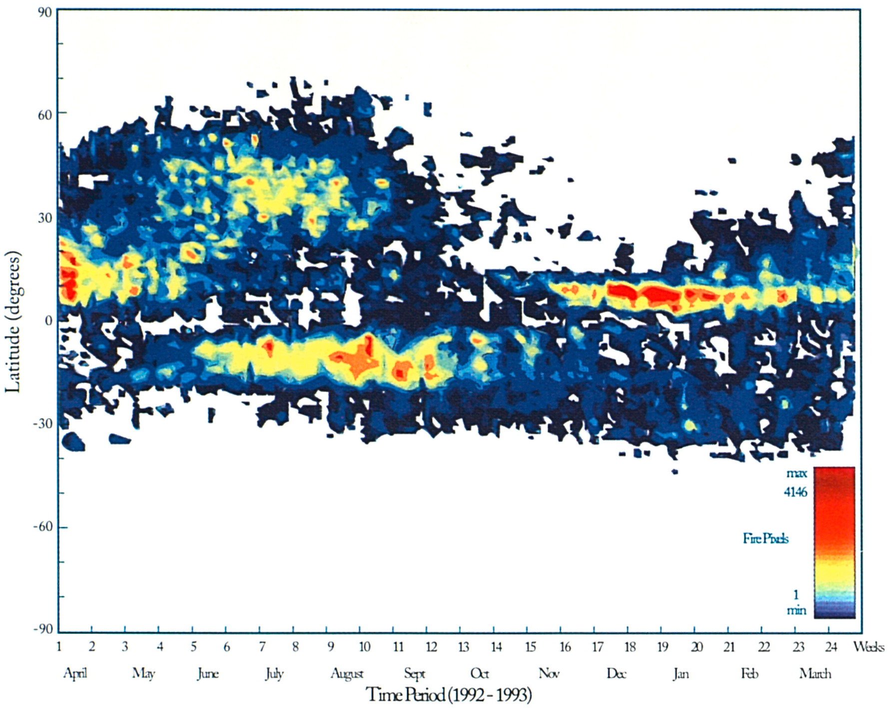


Figure 5.1 : Temporal dynamics of observed burning at global level a a function of latitude, from April 1992 to March 1993, as derived from NOAA-AVHRR 1km resolution imagery.

maps of fire distribution and burnt surfaces for the Northern edges of the rain forest domain of the Congo basin and for the seasonal forest and woodland formation of the sudano-guinean region.

A set of standardised biomass burning products has been implemented at different scales, from global to regional and local, and made available to the external user community.

Development of tools and methodologies

For many environmental issues, two key items of information are the extent of territory burnt and the amount of burnt material. This is why MTV has launched two research actions on this subject. The first is based on the design of Vegetation Indices, derived from the AVHRR data. The second relies on the data from the ATSR sensor onboard the ERS satellites.

Studies of the mapping of burnt areas from AVHRR conclude that a modified version of the Global Environment Monitoring Index (GEMI), where the reflective component of AVHRR channel 3 replaces channel 1 in the computation of the GEMI, is probably the best index currently available to detect burnt surfaces.

This modified GEMI has been used, in a collaborative work with the University of Lisbon, to produce burnt areas maps for the Central Africa region. Preliminary results, although not validated by high resolution imagery, suggest that such modified version of the GEMI provides good estimates of burnt areas (Figure 5.2- Mapping of burnt areas from ERS-ATSR imagery).

Recent work over the open savanna regions of the north-east of the Central African Republic, has shown that the Along Track Scanning Radiometer (ATSR) instrument, onboard the ERS satellite, can be used to provide information on both the extent and the rate of biomass burning.

The development of a software package for the pre-processing and analysis of NOAA-AVHRR images

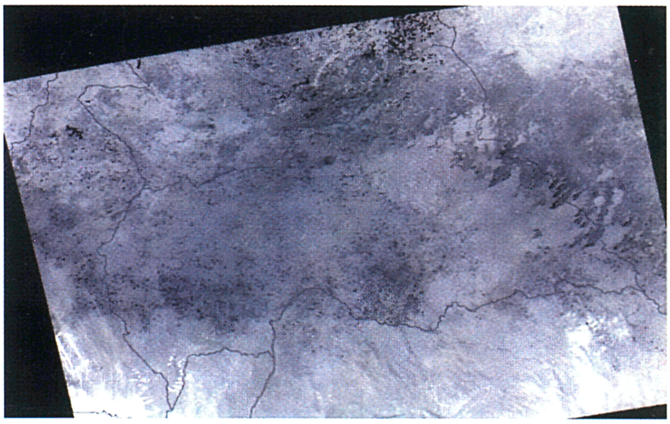


Figure 5.2 : Detection of burnt areas (dark grey and black on the figure) over the savanna-forest zone of Central Africa: Use of the GEMI-3 Vegetation Index developed by MTV.

acquired with a portable receiving station has been a key 1996 activity. MTV has developed the use of a system dedicated to the local acquisition, pre-processing and processing of NOAA-AVHRR images for field operations in Africa and Asia in close collaboration with the UK's Natural Resources Institute (NRI). Operated in the framework of the TREES and FIRE projects, the system has proved its usefullness during field experimental campaigns and for regions outside range of conventional grond receiving stations, or those without systematic acquisition program.

The prototype version of the processor has been improved more particularly in terms of geolocation accuracy, which is now within 1 or 2 km, instead of the former 5 km accuracy.

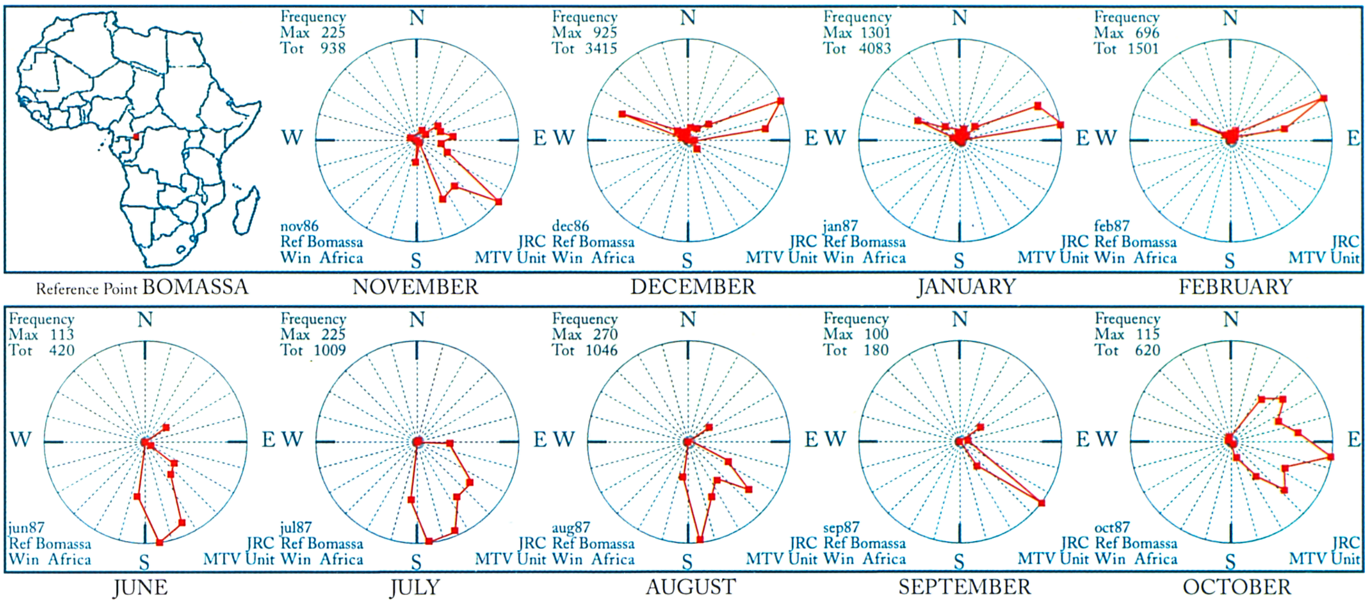


Figure 5.3 : Seasonal dynamics of biomass burning activity around the rain forest of Congo, as derived from monthly fire maps during the period November 1986 to October 1987.

Contribution to IGBP core projects

The MTV-FIRE project's contribution to IGAC has been further developed in 1996 in the framework of the intensive EXPRESSO experimental campaign in the Central African Republic and in the context of the IGAC-DEBITS programme. Figure 5.3 shows the seasonal dynamics of biomass burning as derivable from the rose diagram frequency analysis of monthly fire maps during the period November 1986 to October 1987, around a reference point located in the rain forest of Congo.

The MTV-FIRE project is also contributing to IGBP-DIS, in the framework of its Global Fire Product activity: processing tools and resulting global fire distribution maps are made available to the scientific partners involved in the IGBP Core projects, and more specifically to the IGBP modelling community.

The analysis of the relationships between patterns of fire distribution and the degree of fragmentation of the tropical forest, in the framework of the TREES-II project.

An analysis of the spatial distribution of fires, as derived from the Global Fire Product, has been done in relation to the boundaries and fragmentation level of the dense forest, defined by the TREES project, for the African Continent. This analysis should help in the identification of forest areas that may be undergoing deforestation.

Perspectives for 1997

The Global Fire Product activity will be pursued to:

- complete the systematic processing of one whole year of global data, following the GFP Prototype specifications accepted by IGBP-DIS
- organise a validation procedure of the results, in coordination with IGBP-DIS. A validation workshop is planned for September 1997
- propose a distribution mechanism, for the GFP, based on the WWW facilities.

The MTV contribution to IGAC-EXPRESSO will continue in 1997. MTV has been nominated Principal Investigator by the EXPRESSO Scientific Committee for the activities dealing with the characterization of biomass burning, within the overall research programme of the experiment. As such, MTV will coordinate the researchs of a group of 6 co-investigators, from 5 european member states: Danemark, United Kingdom, Belgium, France, Portugal and Italy.

The analysis of biomass burning patterns in relation to land use- land cover dynamics will be strengthened with 2 well defined actions:

- the integration of fire related information into the Tropical Forest Information System (TFIS) of the TREES-II Project, in order to help in the identification and monitoring of deforestation areas in S-America, Africa and S-E Asia
- the submission to DG IB-D4 of an operational fire monitoring project for Vietnam. This joint Vietnam-EU proposal will have as core objective to improve forest policies in Vietnam, and more particularly the planning and control of forest land use in the current situation of rapid economic liberalisation.

In collaboration with ESA, a dedicated effort will be done to inlude the ATSR instrument, onboard the ERS-2 satellite, in the earth observation systems used by MTV for global monitoring of fires and vegetation.

5.2

Land cover and Environmental monitoring in tropical regions: the MERCATOR project

Summary of objectives

To describe and explain the state and recent changes of the inter tropical environment at continental scales.

1996 Milestones

January: HIMS test and evaluation started

May: evapotranspiration study finished

June: Africa IGBP land cover mapping started

September: Africa IGBP land cover mapping finished satellite data and models started

November: HIMS test and evaluation finish

1996 PROGRAMME OF WORK

Introduction

The MERCATOR project (Monitoring Ecosystems with Remote sensing and Cartography of African TrOpical Regions) was set up to cover a broad range of environmental monitoring aspects, with a special attention to small scale land cover and land use mapping. This project, currently focused on the African continent, is a contribution of the MTV Unit to the IGBP-DIS and LUCC activities.

Sub-continental pilot-project:

Assessment of apparent evapo-transpiration with AVHRR thermal channels.

Vegetation indices, such as the normalised difference vegetation index (NDVI), have become a standard tool for crop monitoring, biomass amount assessment and vegetation mapping. The situation differs for what regards evapotranspiration assessment, which is traditionally obtained from ground measurements, or a combination of satellite data and ground measurements. For

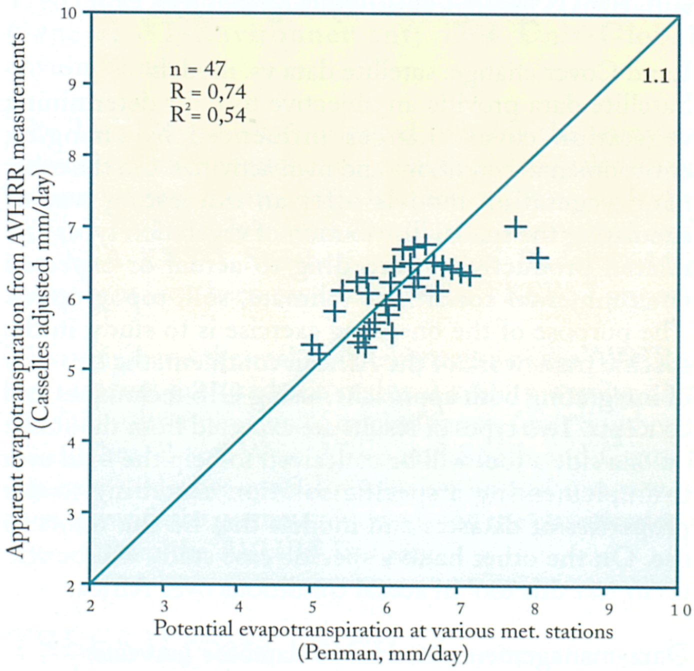


Figure 5.4 : Graph showing the relationship between AVHRR-derived and ground-based evapotranspiration. Potential evapotranspiration is computed from measurements in met stations with the Penman formula. "Apparent" evapotranspiration is computed from surface temperatures derived from AVHRR data and the Caselles formula adjusted to local conditions of the area considered (West Africa from the rainforest to the desert, 9° W-6° E, 4° N-20° N).

environmental monitoring of African regions, it was thus found useful to test the feasibility of using a procedure that would be entirely based on satellite data, even at the expense of a reduced accuracy. This study was carried out jointly with the Geomatics Department of Laval University. A data set including daily AVHRR 1-km data and detailed agrometeorological measurements was assembled over West Africa. The CASELLES method was chosen after an extensive literature review: this is based on a combination of AVHRR-derived surface temperature, and computed global radiation. The Apparent Evapo-Transpiration derived from CASELLES was within 15% in agreement with potential Penman's evapotranspiration, provided that non vegetated areas and dormant vegetation were masked out.

An apparent evapotranspiration index based only on AVHRR data, developed and tested over an ecological transect of the African continent (Figure 5.4).

Continental land cover mapping of Africa

In the framework of the International Geosphere and Biosphere Programme, a first draft of the AVHRR-derived "1-km land cover map" of Africa was jointly produced with the US Geological Survey. An unsupervised classification scheme was applied on 12 1-km AVHRR NDVI monthly composites. Each class was then labelled according to the IGBP land cover legend using reference material collected by MTV (maps, reports, high resolution satellite imagery). The draft version of the land cover maps now available for assessment and comments at the following WWW address: http://edcwww.cr.usgs.gov/landdaac/glcc/glcc.html. A preliminary version of the IGBP - 1km land cover map of Africa produced and validated in co-operation with the US geological survey (Figure 5.5).

Land Cover change: satellite data vs. models

Satellite data provide an objective tool for determining vegetation cover changes influenced by changing environmental conditions and man activities. On the other hand vegetation models offer an interesting way of simulating the spatial distribution of vegetation types and related productivity, according to actual or expected environmental conditions (climate, soil, topography). The purpose of the on-going exercise is to study, in the specific framework of the African continent, the best way of integrating both approaches using GIS techniques and concepts. Two types of results are expected from the study: on one side a tool will be conceived to help the final user in implementing a specific solution according to the properties of datasets and models that he/she wants to use. On the other hand a specific case study will be set-up to test this tool in actual conditions over Africa.

Data-management: the HIMS database harvester

Analysing environmental phenomena at global scales, such as tropical forest evolution, biomass burning and land cover dynamics, requires the use of reference information from various sources. Among those high resolution (10-100 m) satellite data play a special role. They offer relatively standardised and objective views of small portions of the Earth, from which more general observations retrieved from low resolution (1-10 km) satellite data can be validated. To facilitate end-users work, the HIMS concept was developed and fully tested in 1996. Its basic principle is to offer a "one-stop-shopping" entry point for high resolution satellite image location. This objective is achieved by using an off-line "data harvester" tool that automatically interrogates once a day remote databases maintained by providers, retrieves the information on new acquisitions, re-formats it and updates a local

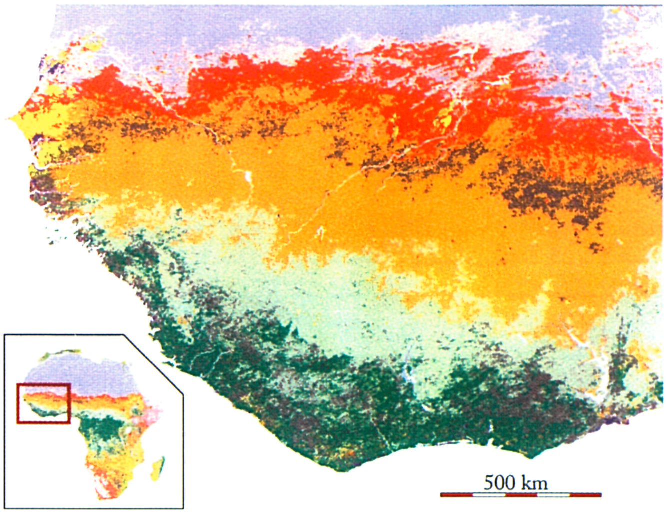


Figure 5.5 : Detail of the IGBP land cover map over West Africa. This was obtained by unsupervised classification of monthly vegetation indices and class identification with reference material.

database that can be easily accessed with off-the-shelf Web browsers. As the number of data providers maintaining product databases increases steadily on a global basis (more than 40 providers have been found by end of '96), the off-line approach was found to be a most reliable and cost-effective approach, as no operator is involved in query procedures and data entry, and no time is lost in waiting for good communication connections on computer networks. After 8 months more than 4 million entries were captured and stored. This induces a major burden on the database system which has to be tuned accordingly. The concept of an operational HIMS package is now being defined and proposed for final development.

Perspectives for 1997

Integration of climatology-driven vegetation models and satellite data will be undertaken, with a special attention to the effect of input data accuracy on final results, in three different time-frame conditions: Seasonal variations, inter-annual variations (2-5 years) and "long term" trends (10-50 years).

Prospective studies will be carried out and project proposals will be prepared on the implementation of land cover monitoring techniques of non-European territoires in support to E.U. sectorial policies, with a special attention to desertification and land resources for agriculture.

5.3

TREES: Tropical ecosystem environment observations by satellite

Summary of Objectives

- Development of techniques for a global tropical forest inventory using AVHRR and ERS-1 as the main sources of data supplemented by high spatial resolution optical data (SPOT and Landsat), (TREES phase I: 1991/1995).
- Development of techniques for the detection and monitoring of the active deforestation areas; measurement of deforestation rates in critical areas (TREES Phase II: 1996/1999).
- Development of a comprehensive Tropical Forest Information System to support the modelling of tropical deforestation dynamics.

1996 Milestones

1996 was the first year of the TREES II project (Support to Commission: DG XI);

February: signature of the administrative agreement between DG XI and JRC defining the TREES II project: "Development of a prototype for a system of global tropical forest monitoring ".

June: production of global statistics of tropical forest areas;

September: production of the first draft of the Central Africa vegetation map;

November: production of the first draft of the South America vegetation map;

December: Publication of the TREES I presentation CD-ROM.

1996 PROGRAMME OF WORK

Introduction

Monitoring change in the forests of the tropical belt presents a formidable challenge. In order to address this issue a project, funded with financial resources outside of the framework programme, was initiated in 1991 entitled the TREES Project (Tropical Ecosystem Environment observation by Satellite). A second phase was initiated in 1996 under support to Commission funding (Directorate General XI-Environnement; D/4 Unit-Global environnement).

The TREES project is oriented towards the study of tropical forest dynamics at regional to global scales using remote sensing techniques. Data derived from both the NOAA AVHRR low spatial resolution instrument and the ESA ERS-1 Synthetic Aperture Radar (SAR) instrument have been considered in the TREES I project.

The optical and thermal channel imagery of the AVHRR instruments are used for regional scale mapping and condition-determination of tropical forests (over Southeast Asia, Central and West Africa and South and Central America). Higher spatial resolution optical imagery is used to verify the patterns observed, and the classifications derived from the AVHRR imagery.

TREES II phase

The second phase of the TREES Project focuses on the development of a prototype for monitoring tropical forests at a pantropical scale. This second phase relies on the know-how, data sets, and systems established at the JRC during TREES I and upon a series of new developments. 1996 was mainly dedicated to:

1. the consolidation of all the information available in the TREES project Phase I in a validated and shareable form,
2. the setting up of new arrangements for the provision of data and their analysis using improved and state-of-the-art techniques, and
3. the initial opening of the project information system to a range of institutional users and partners.

The following is a short assessment of the current status of activities in the five modules foreseen during the first year of TREES II activities.

Module 1: Data and Information Collection. The data acquisition plan has proceeded as planned with respect to satellite data and ancillary information:

1. Arrangements have been made for initiating a regular coverage of all the tropical areas using the low resolution AVHRR satellite. Access to global data sets assembled in the framework of other activities (i.e. IGBP) has been secured. Local AVHRR data are being acquired on an ad-hoc basis by the portable TREES-FIRE receiving station.

2. Radar data which are increasingly considered as a major source of information on forest distribution and conditions have been acquired in large number; these form the blanket mosaic coverage of the rain forest domain of Africa; additional coverage is being provided by the Japanese Space Agency (JERS-1).

3. The more expensive high resolution data have been acquired for selected "hot spot" areas on a trial base; more sites have been studied jointly with the FAO through the Link Project funded by the Tropical Forest Line in DG I.

4. Thematic and cartographic data base has been expanded to the widest extent possible and integrated in the TFIS (Tropical Forest Information System -see Module 4) which now constitutes a major source of data on the tropical forest cover in the world.

5. Informal and non-structured sources of data on deforestation have not been exploited yet and more work needs to be done on this issue in the second year.

Module 2: Remote Sensing Data Analysis. The analysis of existing and updated data sets on tropical forest cover and distribution has led to a few major types of outputs:

- continental forest distribution maps;
- statistical forest cover tables;
- global and continental fire maps.

- the maps covering Africa and South America have been undergoing a full peer review process by a wide rage of international and national experts from Europe, the US and the regions themselves. As a whole the maps were extremely well received as useful "regional" cartographic and thematic data sources.
- the statistical data which are presented in country tables have now been systematically compared to the official FAO statistics. The analysis has lead to adjustments in the analysis methods.
- the interface between global fire and vegetation cover maps has provided unique views on the coincident distribution of those ecosystems characteristics; the combined sets will be intensively used in modelling deforestation.

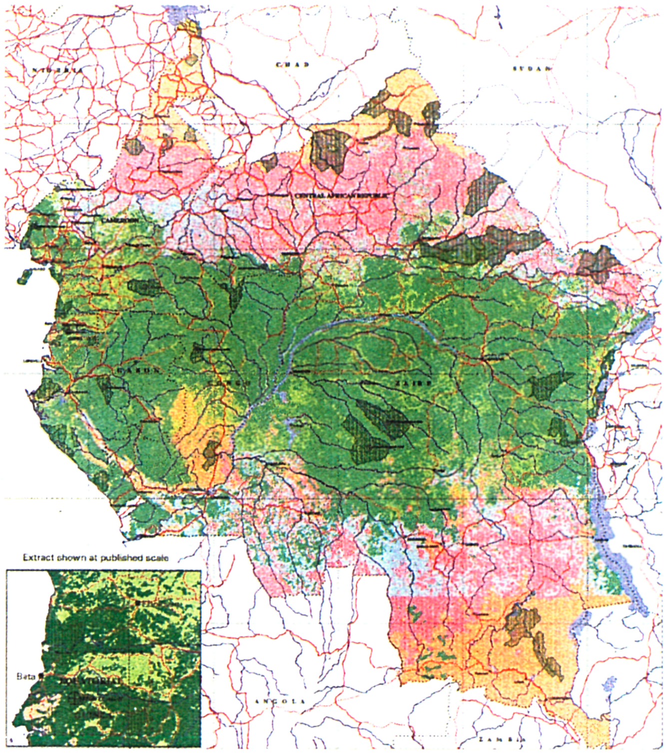


Figure 5.6 : Reduced view of the Central Africa Vegetation Map.

The selection of "hot spots" which will represent an important focus of the TREES II activities has been initiated; however there is a need for formalising the definition and selection of those regions where active deforestation is taking place.

Module 3: Research & Development. R&D has continued to feed the TREES core activities with new advances in remote sensing analysis and in information system management. The highlights of this activity in 1996 were:

- change detection and measurement in complex terrain using high resolution satellite data at selected intervals of time;
- improved processing of satellite data for the detection and positioning of fire in vegetation at local, continental and global scales;
- radar image analysis for better characterising forest-non forest interfaces and integration of such analysis in the mainstream of TREES Module 2;
- better characterisation of forest canopy architecture through field measurements, modelling and remote sensing analysis.

Modelling work has been initiated during the first year of TREES II. An important exercise has been produced which relates spatial deforestation features to a series of driving forces in the case of Thailand. The approach can be followed in support to a very crucial analysis of deforestation trends and will be extended to the pantropical level.

Module 4: Tropical Forest Information System. The tropical forest information system (TFIS) has been expanded via the acquisition of new data sets from a wide range of sources. It has been organised in order to become more user oriented.

A major feature of the evolution of the system has been its opening to outside interrogation via the establishment of satellite TFIS Workstations (notably with DG XI).

The TFIS has also seen new development in cataloguing and extraction facilities which is a critical point in any global monitoring exercise. The production of deliverables identified in the present report has also been integrated in the TFIS framework.

An improved statistical calibration procedure for quantitatively assessing the forest cover using low resolution satellite data has been developped and fully integrated in the TFIS.

Module 5: User Interface. The User Interface represents the "window" of the TREES Project to the outside world. This module plays an important function with respect to the acceptability of the project by the international community. During 1996 a series of concrete actions have been taken in order to maintain, improve or otherwise open new contacts with a series of individual partners and institutions:

- pilot projects have been identified, negotiated and in some cases initiated with Zaire (SPIAF), Vietnam (FIPI) and Brazil (EC Delegation-INPE);
- a link between the TFIS and DG XI for data communication and exchange is being implemented;
- joint data analysis with FAO has been further reinforced; full integration with the World Bank regional Central Africa Project (REIMP) has been arranged; an agreement for data exchange has been finalised with the NASA Landsat Pathfinder Project and a network of European investigators continued to be used for the realisation of specific tasks;
- an interactive CD-Rom containing documentation of the TREES I phase was produced and a TREES leaflet has been printed for large distribution;
- discussions have been held with respect to the role of TREES in the future International Convention on Forests and with CIFOR with respect to forestry research.

Perspectives for 1997

During the second year of the TREES II Project (1997), the JRC will focus on the following points:

- initiation of the regular wall to wall coverage of the tropical belt using low resolution data (AVHRR but also others such as RESURS, IRS-C, etc...);
- streamlining of data acquisition and processing;
- identification and stratification of a series of "hot spots";
- design of a statistical sampling strategy to conduct a calibration exercise;
- measurements and analysis of change areas and processes;
- first steps of pilot studies: Zaire, Vietnam and Brazil.

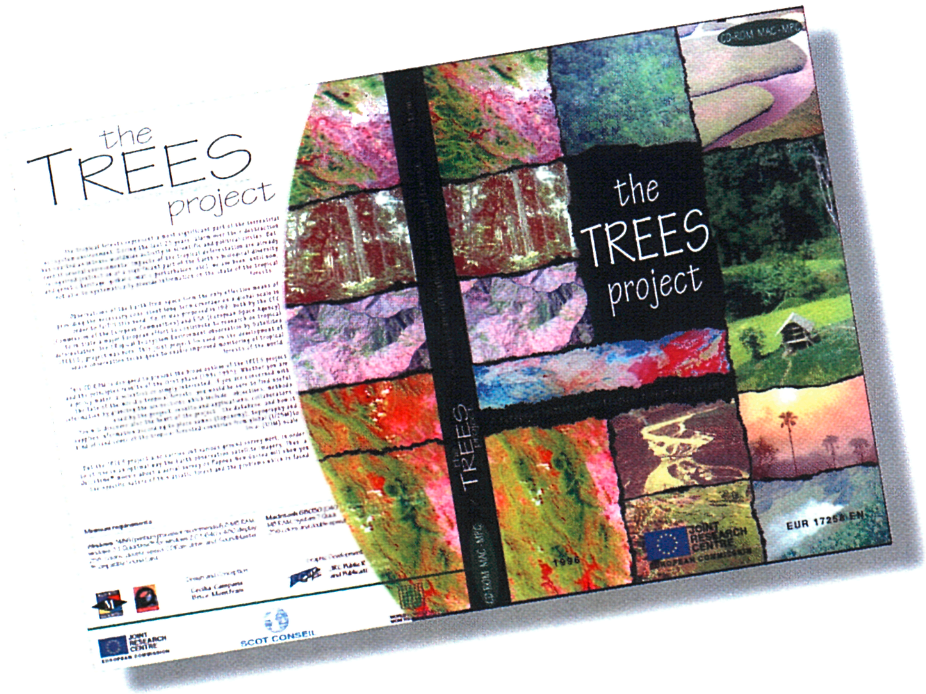


Figure 5.7 : CD-ROM Cover Box.

5.4

SAR Data analysis in the context of the TREES Project

Summary of Objectives

This work is intended to prepare the ground for introducing at a later stage space-borne Synthetic Aperture Radar SAR technology into the TREES operations.

1996 Milestones

The CAMP (ERS-1 Central Africa Mosaic) processing chain was fully characterized
a new version of the CAMP mosaic was generated.

1996 PROGRAMME OF WORK

Introduction

Four major research avenues have been pursued in 1996. These were large scale mapping of the tropical forest, ecosystem temporal evolution, topography and radar polarimetry.

Large scale mapping

The CAMP (ERS-1 Central Africa Mosaic) processing chain was fully characterized and a new version of the CAMP mosaic was accordingly generated.

The CAMP thematic interpretation has progressed to support a number of studies, among which:

- A regional assessment of forest cover
- The estimation of land cover changes in Nigeria in collaboration with Hunting Services Ltd. UK.
  An algorithm for the automatic extraction of texture measures from CAMP has been investigated, and a network of European partners has been set in place to promote the use of the CAMP data set in several thematic contexts.

A processing chain for the NASDA GRFM program has been designed and implemented to process the images involved in the Africa part of the project (approximately 4000 SAR high resolution). This new chain will be at the core of the generation of all future large scale radar maps within TREES. Finally the data acquisition and processing of the second CAMP coverage (ESA ERS-2 sensor) has been initiated in collaboration with the D-PAF Libreville station, and the DLR.

Ecosystem Temporal Dynamics

An original approach for the estimation of the radar reflectivity using multiple SAR scenes has been investigated. It allows to estimate the spatial and time evolution of the radar backscattering coefficient preserving the original spatial resolution, but with a signal to noise ratio which allow for unprecedented thematic interpretations of the radar images (Figure 5.8).

Topography

Issues related to the impact of topography on the geophysical information extraction in the context of the operational strategy of the TREES project were investigated. A methodology based on georeferencing technology was tested on a well characterized site in West Africa. Moreover a neural network solution to the problem of the supervised

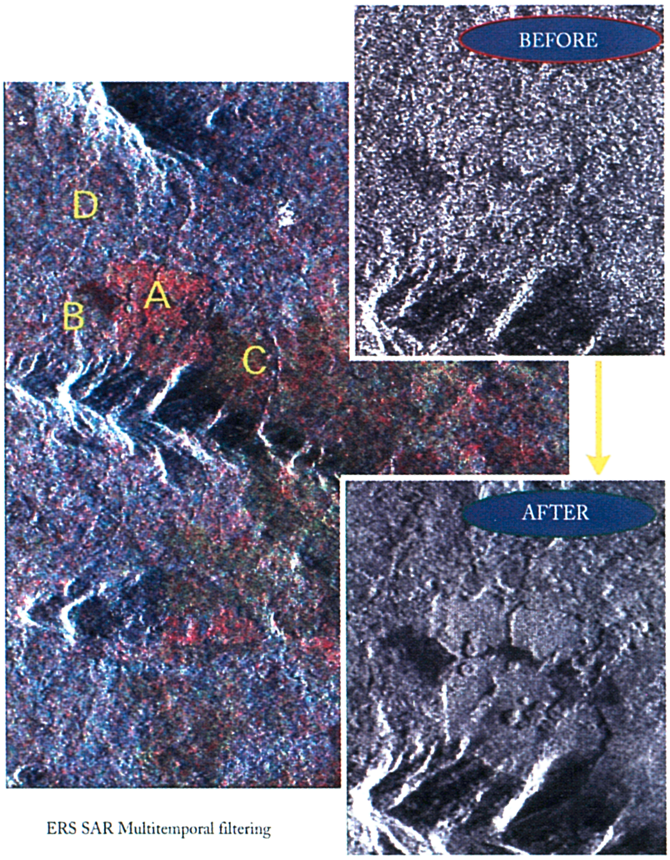


Figure 5.8 : Radar Reflectivity Estimation Using Multiple SAR Scenes of the Same Target. A time series of 18 radar scenes over the Sassandra forest in West Africa were used to obtain an estimation of the radar backscattering coefficient at the original spatial sampling rate (12.5 m) from the signal buried in multi-plicative noise (speckle). The recovery of the underlying radar cross section makes it possible to exploit the spatial characteristics of the signal (which would be otherwise concealed by noise) for the extraction of thematic information, such as the primary-secondary forest boundaries.

classification of SAR data in the presence of sloping terrain was tried out. This study established the theoretical background for the applicability of such an approach in the thematic context of the TREES tropical forest mapping.

Polarimetry

An algorithm to derive topographical information from polarimetric SAR data was proposed and characterized in collaboration with the Naval Research Laboratory Washington DC USA. The algorithm has been validated experimentally using data sets acquired over different geographical areas, over different types of natural targets (forest, bare soil) and using different digital elevation models as reference system. The polarimetric approach proved to be a viable alternative to the interferometric approach especially for monitoring topography over dense forested areas, and on large geographical scale.

A study on the texture and speckle statistics in polarimetric SAR synthesized images was carried out. Application to experimental polarimetric radar data sets forest reveals some distinct and interesting trends in the texture signatures. The important conclusion of this research is that the polarimetric texture signature is a discriminator of weak targets against a clutter and of structural properties of the target, when only polarimetric diversity and not radiometric diversity plays a role.

Perspectives for 1997

The bulk processing for continental scale radar mapping of the tropical forest in West and Central Africa will be completed. This will include the Japanese JERS-1 coverage in the context of the GRFM (Global Rain Forest Mapping) NASDA program, the second ESA ERS acquisition for the TREES Project, and the Canadian RADARSAT sensor's imagery acquired within the ADRO program. This relevant effort will in the end produce a unique and unprecedented data set over the entire biogeographical domain of Central and West Africa. Parallel activities will be started for the thematic analysis of these global data sets, and new R/D avenues explored in the area of automatic information extraction.

Together with the concurrent efforts of other European and international partners, such as the DLR, Germany, and the California Institute of Technology Jet Propulsion Laboratory, USA, the MTV global radar mapping activity will hopefully lay the ground for a new approach and a new technology for the study of large scale problems of the planet earth, such as the tropical rain forest monitoring.

The same technology for large scale radar mapping will also be at the core of other projects which are now being formalized and where MTV will play a leading role. These are:

1. SEARRI (South East Asia Rice Radar Investigation) a CEO funded project whose aim the assessment of the spatio-temporal signature of rice paddies over regional scale in support to rice yeald modeling, and methane emission assessment.
2. Environmental monitoring by radar maps of the Siberian forest, a proposed joint initiative between the JRC MTV, the Japanese space agency NASDA, the European space agency ESA, and the DLR, (Germany) with the International Forest Institute in Moscow.

5.5

TEAM: Terrestrial Environment and Atmosphere Modeling

Summary of objectives

- To develop and evaluate advanced physically-based models and numerical algorithms to extract reliable quantitative information on terrestrial environments from satellite remote sensing data in the optical domain.
- To demonstrate the use of these advanced methods in practical applications, and to contribute to Global Change research, paying special attention to the integration of modelling and remote sensing techniques.
- To investigate biosphere-atmosphere interactions, both to improve the representation of biological and environmental processes in General Circulation Models of the atmosphere, and to assess the effect of climatic variability and changes on the biosphere.
- To collaborate with national and international Space Agencies (ESA, NASA) on the design and implementation of scientific algorithms for the optimal exploitation of new sensors.

1996 Milestones

January: Award of the ENAMORS Concerted Action (European Network for the development of Advanced Models to interpret Optical Remote Sensing data over terrestrial environments).

May: Selection of a competitive research project by the Japanese Space Agency (NASDA) to design a spectral index optimized for the Global Land Imager (GLI) instrument.

June: Selection by the NASA Jet Propulsion Laboratory of a TEAM-designed algorithm to analyze MISR data.

July: Design of the GEMI3 index to identify and map burned surfaces using AHVRR data in support of FIRE activities.

September: Design of the FACOSI software tool to create spectral indices optimized for particular applications using a specific instrument.

December: Simulation of the transfer of radiation in a tropical forest scene in support of a seasonality study.

1996 PROGRAMME OF WORK

Results

The TEAM group has pursued its exploitation of the Monte Carlo ray tracing model developed earlier. Measurements and field observations gathered from a forest site in north-central Africa were used to describe the structure and properties of a tropical forest scene, and the model permitted the estimation of the spectral reflectance of this forest under typical conditions of illumination and observation.

Work has also been pursued to develop an improved one-dimensional radiation transfer model. The model under development permits the explicit description of the plant canopy as a set of finite leaves for the first two orders of scattering, while the multiple scattering contribution is still described with the help of standard turbid medium theory. This approach permits to model explicitly the role of an anisotropic soil under the vegetation layers. This model is designed to be coupled with atmospheric codes, so as to provide a complete solution to the joint description of radiation transfer in the Earth environment.

The knowledge acquired recently on the design of spectral indices has been implemented into a software tool which allows the creation of optimal indices for particular applications and specific instruments. A collaboration with the Technical University of Lisbon resulted in the testing of a series of spectral indices to monitor fire activity and estimate burned surfaces. Figure 5.9 images the value of two such spectral indices for a region of the Central African Republic, as it was observed by the NOAA 14 AVHRR on December 13, 1995, at a time when heavy biomass burning activity was taking place. A wider section of that image is shown elsewhere in this report. The right panel maps the value of the classical NDVI. The perturbing effect of the smoke layer is clearly seen. The left panel exhibits the value of GEMI3, which is the GEMI index previously proposed by TEAM with Channel 1 replaced by the reflective part of Channel 3. The grey scale was selected in such a way that denser vegetation appears lighter. The many small black dots in the GEMI3 image are local fires: they are clearly visible in this frame even though they are obscured by the smoke veil in the NDVI picture. Recently burned areas are also much easier to identify on

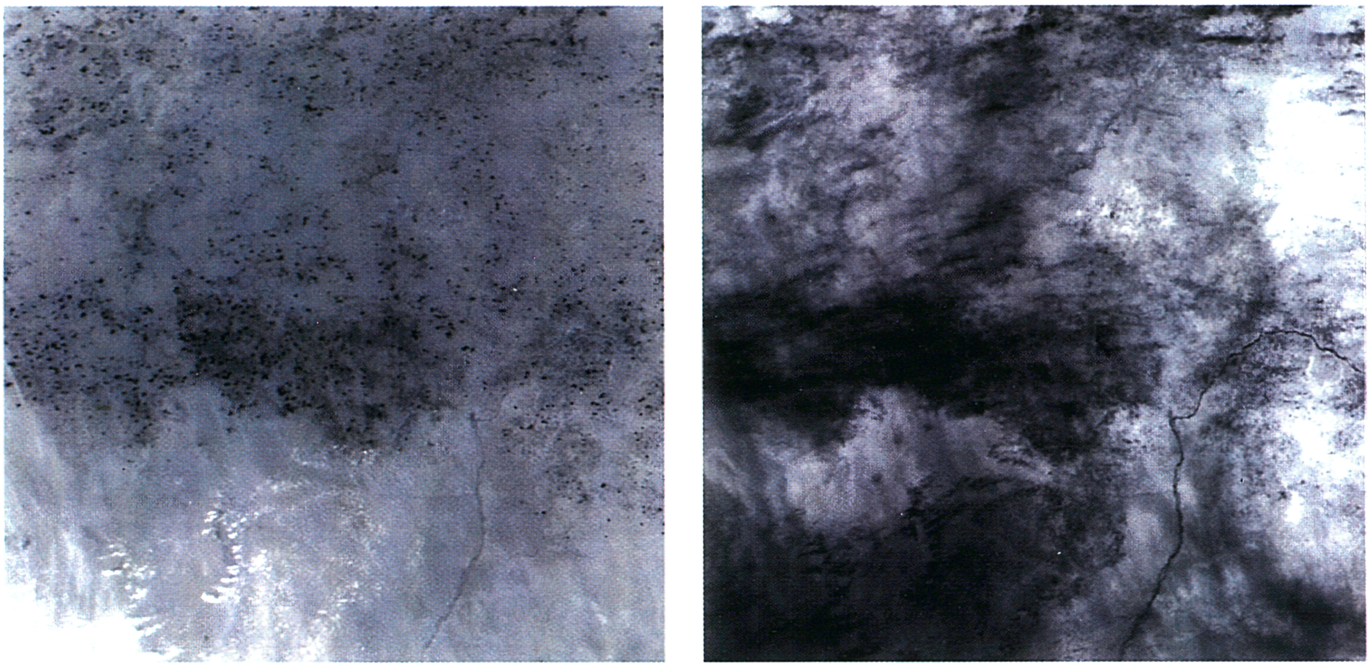


Figure 5.9 : Testing of NDVI (right panel) and GEMI3 (left panel) spectral indices to monitor fire activity and estimate burned surfaces for a region of the Central African Republic, as it was observed by the NOAA 14 AVHRR on December 13, 1995. The many small black dots in the GEMI3 image are local fires and recently burned areas.

the GEMI3 image, as can be seen on the overall picture. These preliminary results are currently being analyzed in detail, and may lead to the development of a spectral index optimized for fire applications.

TEAME´s work on biosphere modeling has been pursued along two lines: First, a version of the Ecological ModUle (EMU), a model designed to understand, simulate, and predict responses of terrestrial vegetation to climate variations has been completed and evaluated using biogeographical maps. The originality of EMU is twofold: EMU embodies fundamental physical and biological principles, and it was conceived from the outset to make use of the kind of information which can be obtained using satellite remote sensing. Maps of the simulated seasonal dynamics of the terrestrial biosphere indicate that EMU is capable of describing the observed vegetation cycles. The interpretation of these maps using ancillary output from EMU confirms the predominant role played by water stress in the tropics and temperature near the poles. They also highlight the crucial function of the Intertropical Convergence Zone (ITCZ) and the North-South oscillation of biological activity, the so-called *"green wave"*, over West Africa. Finally, the maps reveal a vegetation change pattern in Indonesia and South America similar but not identical to the one observed in Africa.

The second line of work was aimed at deriving a new analytical description of the exchanges of physical or chemical quantities, other than visible and near infrared radiation, such as water, energy, carbon dioxide, etc., between a canopy and the overlaying atmosphere, making only a limited number of simplifying assumptions. This approach, originally developed for the purpose of studying interactions between the climate, vegetation, and biogeochemical cycles, was christened *"ESCAPES"* (Exchanges between Structured Canopies And their Physical Environment: a simple analytical Solution). This exchange scheme is being evaluated and is expected to be useful in a number of contexts, such as the estimation of surface fluxes in climate models or the estimation of surface characteristics such as temperature on the basis of satellite remote sensing data.

TEAM members continue to be heavily involved in the definition, exploitation and evaluation of new space instruments. They contribute directly to the work of scientific advisory teams for the MERIS and PRISM instruments at the European Space Agency (ESA), the MISR and MODIS sensors of the US National Aeronautics and Space Administration (NASA), as well as the VEGETATION instrument of CNES and the GLI on board the ADEOS-II platform of the Japanese Space Agency NASDA.

Perspectives for 1997

The development of the latest radiation transfer model in plant canopy is expected to be completed in 1997. The computer code implementing this model will be made widely available to the scientific community. This model will also be coupled to an atmospheric model, to allow the analysis of actual remote sensing data.

Significant progress will be achieved in the definition and testing of new spectral indices. Three particular sensors will be targeted: the VEGETATION instrument on board the SPOT-4 platform of CNES, the MERIS on the ENVISAT platform of ESA, and the GLI on the ADEOS-II platform of NASDA. Efforts will focus on the retrieval of critical information on the state of the vegetation cover, in particular on the fraction of absorbed photosynthetically active radiation. Work will also be pursued to investigate new approaches of land cover classification, using positive identification techniques and advanced look-up table searches. The feasibility of defining a spectral index optimized to monitor active fires and burned areas will also be pursued.

Advanced techniques

The Advanced Techniques Unit enjoyed a number of notable successes during the past year. These included:

- The creation of the first map of tree heights of a large area based on ERS SAR interferometric images; a collaborative project with the Remote Sensing Laboratories of the University of Zurich.
- Significant progress in the design of a mutli-sensor system for the detection and identification of anti-personnel mines.
- The creation of a three dimensional map of the radar reflectivity of a large spruce tree; this was also the first ever three dimensional SAR image of a natural target.
- The identification of structural components of trees by making use of the polarisation characteristics of the radar reflectivity.
- Realisation of an adaptive SAR processing algorithm to detect targets of known signatures being covered by vegetation or embedded in soils; this was the first time such an algorithm has been developed, tested and validated for SAR images.
- Investigation of the use of SAR interferometry for industrial applications; it has been demonstrated that this technique can detect structural changes with a precision of 0.1 mm.
- Completion of a study on environmental changes in northern European countries by investigating the bi-directional and spectral characteristics of lichen and moss in the European Goniometer (EGO).
- Verification of computer simulated BRDF models for vegetative surfaces in the EGO in collaboration with the Institute for Space Sensor Technology, DLR, Berlin.
- Investigation of paper quality based on its components and verification of theoretical models in the EGO; a collaborative project with the University Helsinki and the Finnish paper industry.

Furthermore, a number of important third party work contracts have been conducted, such as:

- Dissemination of EMSL radar signature reference data, CSA (competitive support action) project with DGXIII, (CSA95E1): Started January 1996, First CD-ROM ready since end of 1996.
- Dissemination Network for EMSL Data and Processing Capabilities, CSA project with DGXIII, (CSA96P26): Signed in November 1996, to be started in January 1997.
- RoCoCo study contract, with Daimler-Benz, Ulm: Experimental investigation of the detection of road conditions by radar systems.
- RCS measurement of 6 different types of cars at 77 GHz, third Party work for Daimler-Benz.

6.1 Signal processing

1996 PROGRAMME OF WORK

Summary of objectives

- Retrieval of bio- and geophysical parameters from remotely sensed observations.
- Assessment of the synergy of optical imaging spectrometer (AVIRIS) and polarimetric microwave (AIRSAR) data for forest resources assessment.
- Development of the synergistic use of active and passive microwave sensors.
- Development of new inversion methods for active and passive spaceborne microwave remote sensing of boreal forests.
- Development of an approach for processing of large hyperspectral datasets.
- Assessment of the impact of seasonal and other environmental factors, concentrating on biomass estimation, as well as on forest and land cover type recognition.

1996 Milestones

January: Geophysical SAR (Synthetic Aperture Radar) Processor (GPROC)
Adaptive Maintenance Development kick-off meeting.
March: Final report of the synergy work.
July: GPROC Adaptive Maintenance Development software delivery.
December: GPROC Adaptive Maintenance Development final acceptance.
Completion of the study on the development of inversion methods for microwave remote sensing data of boreal forests.

The JRC Geophysical Processor

A prototype Geophysical SAR Processor (GPROC) was developed under the European Airborne Remote Sensing Capabilities program (EARSEC, 1991-1994) of the Commission of the European Communities co-ordinated with the European Space Agency. The further improvement of this processor started in March 1994 when a specific workshop was organised at JRC-Ispra, with the participation of experts for the selection of algorithms concerning a range of themes. The EARSEC programme was aimed at establishing a pool of resources to support remote sensing campaigns in Europe. It involved establishing a number of UNIX based processing facilities forming the EARSEC Data Fusion Environment (EDFE), of which GPROC is a major component.

The Advanced Techniques Unit of the JRC Space Applications Institute has continued to develop the Geophysical Processor - especially with regard to the land applications and to the man-machine interface (GUI) in order to support in the near future the user community of remotely sensed data in Europe. The upgraded, extensively tested version was delivered to the JRC in summer 1996.

Applications and Algorithms

The Geophysical Processor consists of number of algorithms for retrieval of bio- and geophysical parameters, and a Graphical User Interface (GUI) supporting high-level visual programming and (lower-level) Programming Language Integration (PLI) by using the C, C++, IDL (Interactive Data Language) and Matlab (Matrix Laboratory) programming languages. Applications include forest biomass estimation, vegetation and soil moisture estimation, change detection, maritime traffic monitoring, and oil slick detection.

GPROC is originally aimed at scientific users of SAR data - but, nothing prevents its use with thermal and optical data as well. This is done visually by clicking the icon of the wanted application, and assigning the input data files to be processed. The user may view the intermediate results of each processing stage and repeat any parts of the chain where results were unsatisfactory, with new parameters. Thus, the unsurpassed image processing capability of the human brain can be utilised side by side with the computer algorithms.

The development of new applications is supported by visual programming techniques in the form of block diagrams. The system architecture is such that it is easy to add new processes or to substitute alternatives at selected stages of processing. The user thus has considerable flexibility and control over the system operation.

To develop, and finally implement the inversion algorithms on a common basis of GPROC guarantees that they can be easily accessed by the scientists through the computer network, and not be "forgotten" as tends to happen with separate algorithms. In addition, GPROC makes the applications available in a standard way. This greatly helps running and working with the various applications.

GPROC can receive data from the air- and satellite borne SAR data processing chains (e.g. EARSEC EMISAR and ERS-1/2). In addition, Canadian RADARSAT, NASA/JPL AIRSAR, and any general format data can be ingested. In the future, ENVISAT-1 and METOP could be added to the list. The latter two will be supported by campaigns addressing algorithm development and geophysical validation giving good prospects for the continuation of current scientific studies.

One example successfully investigated during 1996 was the synergy of optical and polarimetric microwave data for forest resource assessment. Data acquired during the Mac-Europe 91 campaign over the Black Forest (Germany) were used to study the synergy of optical imaging spectrometer data and polarimetric microwave data for forest resource assessment. Original and new derived bands from the multi-parameter SAR sensor AIRSAR and the multispectral imaging spectrometer AVIRIS data were used to predict age and biomass. The best predictors were selected through a multivariate stepwise regression analysis of each of the datasets separately. Then, the joint AIRSAR-AVIRIS dataset was analysed. This study showed how the synergistic use of AIRSAR and AVIRIS data can significantly improve the predictions for both age and biomass.

At the same time a new approach for processing large datasets provided by imaging spectrometers was developed.

While optical systems provide information on the vegetative condition of the forest, microwave data help in describing its structure and provide information on the physical and dielectric characteristics of the forest. In addition, microwave data are not limited by atmospheric conditions or the time of the day. The synergetic use of both types of data can provide a more comprehensive description of forest resources.

Few studies exist on the combination of SAR and optical data for resources assessment, and these have almost exclusively dealt with space-borne remotely sensed data. Prior to this work there have been no studies on the evaluation of combined airborne multipolarization SAR and imaging spectrometer data for forest resources assessment.

The synergetic use of AIRSAR and AVIRIS data improved the predictions significantly. This implies that microwave and optical data are complementary by their nature. However, the performance of the existing space-borne SAR channels is poor alone, but can be used in synergy with optical data to slightly improve its performance.

A further use of the GPROC tool set has been the synergy of active and passive microwave data as well as their inversion.

Active microwave remote sensing of boreal forests
Current SAR sensors have good spatial resolution, but their radiometric resolution is moderate. The backscattering of forests is a combination of the backscattering from both ground and vegetation. Moreover, studies have shown that the seasonal effects, such as soil freezing and thawing, snow cover and soil wetness, drastically change the level of backscattering in the boreal forests. The correlation between the biomass and the backscattering coefficient is also dependent on the factors mentioned above. Nevertheless, these seasonal effects may benefit the inversion if suitable models are used with a multitemporal data set.

Moreover, the direct application of the backscattering coefficient for forest inventory is limited by signal saturation. The lower SAR frequency bands (P- and L-band) are more suitable for biomass measurements than the higher ones (C- and X-band). The P-band would be the most promising for biomass measurements, but it is not available on space-borne sensors. The Japanese JERS-1 satellite has a L-band HH polarization SAR which is the most useful of current satellite radars for forest biomass estimation. The higher frequencies are more suitable for discriminating different forest and land types, however. Unfortunately, the VH polarization, which is the most promising is not available on satellite sensors, and VV polarization alone has a relatively moderate capability. Therefore, ERS-1 data (C-band VV polarization) should be combined with Radarsat data (C-band HH polarization). Radarsat can also provide variable incidence angles, which can benefit the inversion.

Passive microwave remote sensing of boreal forests

In comparison to the active sensors, microwave radiometers have good radiometric accuracy and very large coverage, but only moderate spatial resolution. Therefore, radiometers could be especially useful for global monitoring while SARs provide more detailed local information.

Interest in these passive sensors is growing, and the introduction of a 90 GHz channel gives an improved spatial resolution (about 10 km). Moreover, ESA is planning to launch the Multifrequency Imaging Microwave Radiometer (MIMR) which will also have a 90 GHz channel. At the moment the SSM/I (Special Sensor Microwave Imager) is the only space-borne sensor that can provide space-borne data for the 90 GHz frequency band.
The seasonal snow cover causes relatively large changes on the brightness temperature of the boreal forests. The brightness temperature for forest vegetation is close to its physical temperature while the brightness temperature for dry snow is relatively low at frequencies above 10 GHz. Therefore, in winter the total brightness temperature is related to the forest canopy. Nevertheless, in wet and snow-free conditions this relation is weak because the emissivity of ground and that of the forest vegetation are close to each other.

The main limitation of the space-borne microwave radiometry is in its spatial resolution. Consequently, only a few radiometry studies have been associated with the boreal forests. Moreover, these studies were mainly concentrated on land-type classification. Due to the moderate resolution, a "mixed pixel" approach was used in the analyses. This offers three possibilities: a) each pixel spatial shares of different areas types are known and their emissivities are calculated, b) in each pixel emissivities or brightness temperatures of the different area types are known (or modelled) and their spatial shares are calculated, and c) the combination of a) and b).

Development of inversion methods for space-borne SAR data

The textural information of the seasonal set of ERS-1 and JERS-1 SAR images has been studied with first and second order statistical measures. They have shown a higher information value than the principal components analysis of intensity images for the forest and land type classification. If only one image is used at a time, then neither the textural nor the intensity information was adequate for classification.

An indirect inversion method was developed to estimate a forest-stand-wise stem volume from JERS-1 and ERS-1 SAR images. The method is based on a semi-empirical backscattering model. The model assumes that the backscattering of a forest canopy is defined by stem volume, soil moisture and vegetation moisture. The inversion algorithm has three steps and it is carried out as follows:

1. For training areas, soil moisture and vegetation moisture is estimated from backscattering coefficients and stem volume with the model. The soil and vegetation moisture parameters are interpolated to cover the whole area of interest.

2. For the area of interest, the stem volume is estimated from the moisture parameters and backscattering coefficients with the model.

3. If several SAR-images are used, the stem volume estimates are combined with multiple linear regression. The regression equation is defined with the stem volume estimation for the training areas.

The results for stem volume estimation using L-band and combined L- and C-band SAR data showed promising accuracies: rms retrieval accuracies varying between 45 and 25 m^3/ha, as the size of forest area for which the results are determined ranges from 4 to 50 hectares and the forest stem volume ranges from 0 to 400 m^3/ha.

Development of inversion methods for space-borne radiometer data

The spectral behaviour of emissivity for forest, non-forest and water areas was studied with the mixed pixel approach. In winter the effect of dry snow is obvious and the emissivity of forest separates well from that of non-forest. In summer, the emissivity variation was nominated by water areas, while in winter the nominating factors were forest canopy and snow covered ground.

Even during snow-free conditions, rough estimates of forest coverage can be retrieved with the mixed pixel approach. Nevertheless, the most accurate forest coverage estimates were retrieved during winter conditions. The results show, that a relatively accurate aerial distribution of water, non-forested and forested areas inside a pixel can be estimated with a combination of summer and winter measurements.

An indirect inversion method was developed to estimate the pixel-wise stem volume from SSM/I data. The method is based on the fact, that in winter forest canopy and snow cover are the nominating factors of the measured emissivity. Nevertheless, the emissivity of the snow cover is dynamic; therefore, long term averages are used in the inversion. Additionally, this averaging diminishes the atmospheric disturbances and uncertainties with physical temperature measurements. The inversion algorithm has five steps and it is carried out as follows:

1. The emissivity estimates of the target types (forest and non-forest) are calculated with the mixed pixel approach from the training set. In the test cases, the training set consisted of the 15 weather stations and their surroundings.

These estimates represent the mean emissivities of the target types. In order to unfold the local variation in the emissivities, local emissivity estimates are also calculated by solving the mixed pixel equations separately for the surroundings of each weather station. These local estimates are interpolated to cover the whole test area.

2. The spatial shares of the target types (forest and non-forest) are calculated for each pixel with the mixed pixel approach by employing the measured SSM/I emissivities and the mean target emissivity estimates.

3. The emissivity of forest is calculated from the measured SSM/I emissivity in each pixel by employing the local non-forest emissivity estimate and spatial shares of the target areas (results from the first and second step).

4. For the training set pixels, a multiple linear regression is calculated between the forest emissivity estimate and the stem volume information.

5. For the area of interest, the stem volume estimates are calculated from the estimated forest emissivity with the linear regression equation.

The inversion results for stem volume estimation with SSMI/I data show promising accuracies: rms error from 13 to 19 m^3/ha for a pixel (25 km by 25 km). In the test area, the forest stem volume ranges from 40 to 160 m^3/ha per pixel. These results confirm the hypothesis that space-borne radiometer data could be used for large scale biomass estimation in the boreal zone.

Perspectives for 1997

After testing the final version of GPROC at JRC/SAI/AT and verifying its general performance and stability, the software is ready to be announced and delivered to selected European research institutes. A limited warranty period will end in December 1997, before which all user-responses would be most useful.

Algorithms for polarimetric microwave remote sensing are in an implementation phase, as well as the other methods developed within the Unit.

The synergetic use of optical and microwave data can provide a more comprehensive description of targets of interest. In order to emphasise these findings additional experimental, as well as theoretical, studies and laboratory measurements are anticipated.

All the three space-borne SAR sensors (ERS-1, JERS-1 and Radarsat) should be used in combination, due to their complementing features such as different frequencies, incidence angles and polarizations. This combined approach will be further investigated in 1997. C-band SAR images (ERS-1 and Radarsat) have more capacity for land and forest type classification than for biomass estimation. Thus, this subject is primarily recommended in the analysis of the C-band images. L-band SAR images (JERS-1) are more promising for the biomass retrieval than the C-band. Thus, the capability of L-band images for biomass estimation should be explored with suitable modeling support. Indirect retrieval with modeling seems most promising for multitemporal data.

Multitemporal textural measures significantly improved the classification of land-use and forest types, and this approach will again be adopted in 1997.

Finally, radiometer data will be used to study global forest detection and biomass estimation of the boreal zone.

6.2

European Microwave Signature Laboratory (EMSL)

1996 PROGRAMME OF WORK

Summary of Objectives

- Provide JRC and external users with high quality experimental data.
- Consolidate EMSL international scientific recognition by disseminating its results.
- Increment the use of EMSL for competitive activities.
- Demonstrate and promote new measurement techniques suitable for industrial applications.
- Complement indoor experiments in EMSL with transportable outdoor measurement facility (LISA).
- Continue the collaboration with external institutes to complete planned activities and identify new research areas.
- Continue the development and implementation of processing tools for the treatment of EMSL data.

1996 Milestones

January/December: Experimental activity in the frame of the Thematic Subgroup "Scattering Properties of Non Vegetated Terrain" distributed in several time windows through the year.
April : 1st EMSL User Workshop

April/May: Performance of measurements for Road Condition and Control project (RoCoCo) in collaboration with an industrial partner.
May: First demonstration of applicability of Interferometric SAR techniques to monitor structural deformations.
June: Measurements on coniferous trees in collaboration with external research groups.
First 3-D polarimetric tomogram of a 5 m high fir tree.
6th Meeting of the EMSL Advisory Committee.
October: First high resolution SAR image obtained using the Linear SAR outdoor facility (LISA).
November: Performance of RCSCAR experiment, measuring the Radar response of cars at mm-wave for an industrial customer.
7th Meeting of the EMSL Advisory Committee.
December: Issue of the first EMSL Calendar, on the occasion of the 5th Anniversary of laboratory operation.
Issue of the first EMSL Radar Signature Reference Data Package on CD-ROM, realised in the frame of a VALUE contract funded by DG XIII.

EMSL Operation and Experiment Preparation

Throughout the year measurement activities have taken more than 90% of the facility's occupation time. The rest has been used for experiment mounting work, system modifications and maintenance.

A large part of the measurement activities was dedicated to the experiment series in collaboration with external User Groups in the fields of scattering from Non-Vegetated-Terrain and Vegetation-Modelling. The work for third parties (about 7.5%) has been related to the investigation of road surface backscattering (RoCoCo project with Daimler-Benz/Ulm) and the characterisation of the radar response of cars at 77 GHz (contract to Daimler-Benz/Stuttgart). The latter work has required the temporary integration in the EMSL measurement system of a mm-wave front-end provided by Dornier/Friedrichshafen. The internal activity (about 17%) mainly focused on two topics: subsurface imaging and SAR Interferometry.

To fulfil the requirements of the users a number of new test targets, test set-ups and related test conditioning have been realised. Of particular note are:

- various asphalt road samples with different surface conditions, like wet, icy or with grass borders, for the conclusion of the RoCoCo experiment series
- fabrication of the medium-rough surface mould to shape terrain models. The mould has 2 m diameter, is made of cast aluminium and includes a cooling system; it will be used to freeze large soil samples down to -25 deg for the frozen/thawing soil experiments.
- natural vegetation targets, a large 5m tall fir and a 2m tall spruce tree
- the double-girder concrete structure of 3 m length, for testing the structural deformation detection by SAR interferometric measurements.

A particular effort has been dedicated to implement and possibly improve experimental methods for measuring the dielectric constant of vegetation samples, an essential piece of information in relation to the experimental validation of vegetation scattering models.

The Information Management System (IMS) has been regularly loaded with the data from the new experiments and, to date, 11 projects have been created comprising 45 experiments, for a total amount of more than 3 Gbytes of raw data. The upgrading of existing processing tools and the integration of new ones has been realised as planned. The IMS has been interfaced to a Data Packaging System allowing the structured selection of specific data subsets and related documents in order to create Data Reference Packages for efficient dissemination of results (e.g. by means of CD-ROM or telematic networking).

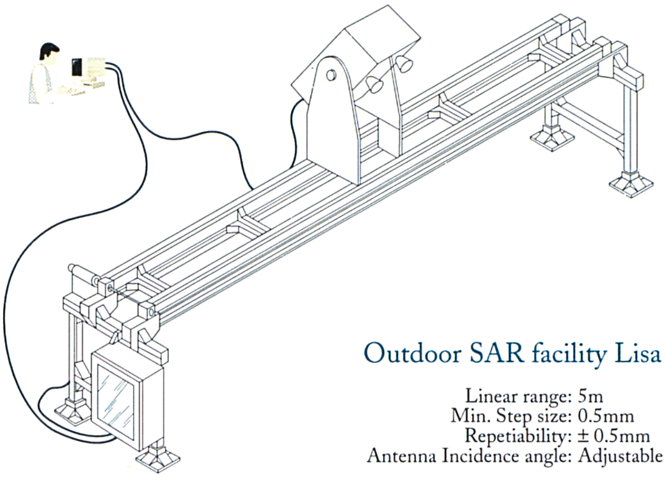


Figure 6.1 : LISA, the Linear SAR measurement facility.

Implementation of the LISA outdoor system

The experimental potential of the EMSL facility was supplemented by an outdoor measurement capacity. LISA, a linear and transportable SAR measurement set-up has grown to its operational state now (Figure 6.1). It was conceived especially for outdoor experiments; so it will cover the multiple outdoor test demands to backup our current and forthcoming research work.

The rail system, made of aluminium profiles, is designed to be very robust and assure accurate positioning even in rugged outdoor situations. The antennas are mounted in a sled-box which is moved horizontally over the 5 m range of the linear rail. The antenna incidence angle can be changed by tilting the box on its support.

The microwave instrumentation is similar to the EMSL equipment: fully polarimetric, coherent imaging capability, working with two-dimensional SAR modes and variable incidence angles. Antenna sets are exchangeable and the frequency ranges can be chosen to meet individual application requirements. At present and for the first applications planned instruments were mounted to cover the range from 30 KHz to 6 GHz.

The measurements are saved in the same formats and structures as EMSL data. This guarantees full compatibility of all experimental data from the two facilities. The LISA data will be stored in the EMSL data archive IMS so it is also available to external users.

The first tests were completed in October in the production of a SAR image of an array of metallic spheres over an asphalt surface (Figure 6.2).

Collaboration with external user group

The Non-Vegetated-Terrain Group experiment series were continued. The measurements addressed validation of surface scattering models and the verification of signal penetration effects on the surface backscattering measurements. The mould to shape medium-rough surfaces for the soil targets became available. So finally the experiments with this surface roughness value could be achieved. The "medium-rough" tests represent the third and last experiments in the series investigating the soil roughness parameter in the backscattering.

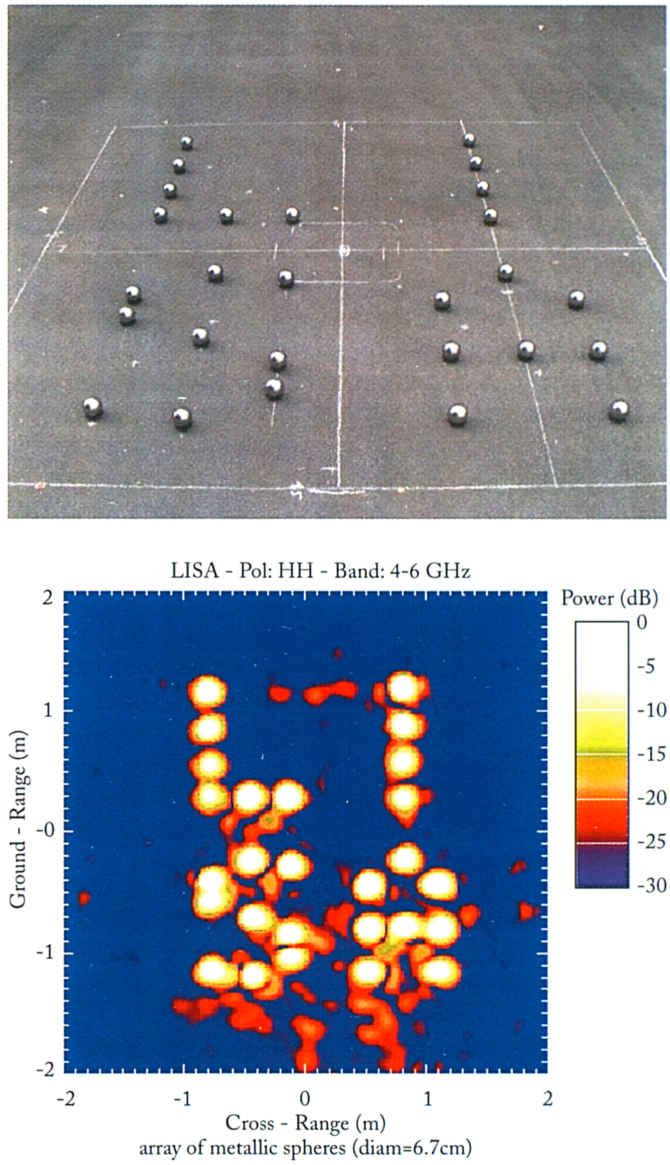


Figure 6.2 : LISA's first imaging experiment target (above) and image (below).

Road Condition and Control (RoCoCo)

The Road Condition and Control project, a collaborative study project between the Daimler-Benz Research Centre at Ulm and SAI was successfully concluded in 1996. The study was aimed at determining the radar backscattering characteristics at typical asphalt road surfaces in well-defined ambient test conditions. Daimler-Benz will use the data in research projects dealing with safety technology developments for automobiles. Specifically the risks of aqua-planing and slipperiness due to rime or glazed frost were addressed.

Three road samples were investigated: the standard asphalt surface found, for example, on highways, one coarser and one finer grained asphalt. From these samples 17 cm thick road targets were built up as 2 x 2 metre square platforms. The targets had to mimic realistic road conditions as closely as possible with regard to structure, compactness and surface. The build-in cooling pipe system can cool down the road samples to frost temperatures, for instance with stable -5 °C on the surface. This provided controlled test conditions for rime deposits or ice layers on the surface.

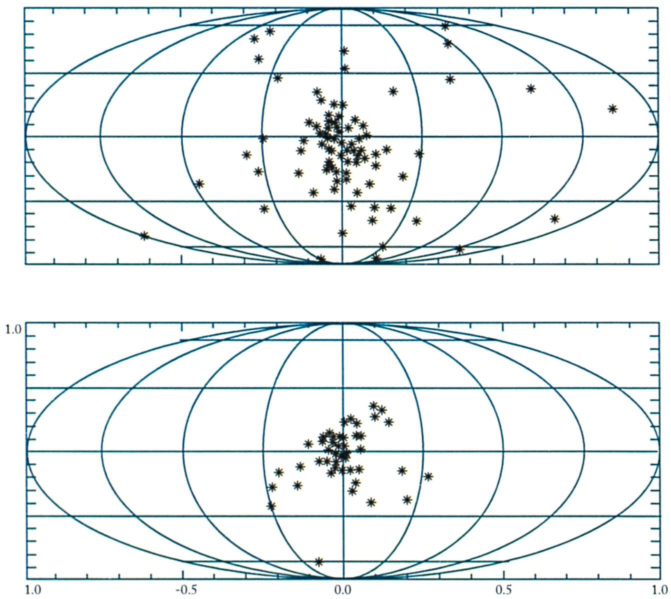


Figure 6.3 : Radar backscatter from asphalt road samples: icy (above) and dry (below).

Two measurement systems were used: the standard microwave instrumentation of the facility in the frequency range 20 to 24 GHz and radar instrumentation from Daimler-Benz working in the millimetre wave range, namely at 76 GHz. Polarimetric radar measurements were made for monostatic backscattering at 44 different incidence angles and for quasi-specular bistatic scattering at five incidence angles. In all cases the measurements were repeated with the road target turned at different azimuth aspect angles in order to generate a number of independent data samples. Some tests used a mobile radar system moving over the road targets at simulated car speeds. These measurements were made with radar sensors for mobile applications and generated stochastic data series needed for the validation of related adaptive on-line signal analysis programs.

The RoCoCo tests series, started in 1995, are now completed. The radar data generated is now being analysed by the research teams. The results so far are very encouraging with respect to the test objectives (Figure 6.3); they suggest that classification of the different road situations and therefore also the monitoring is possible.

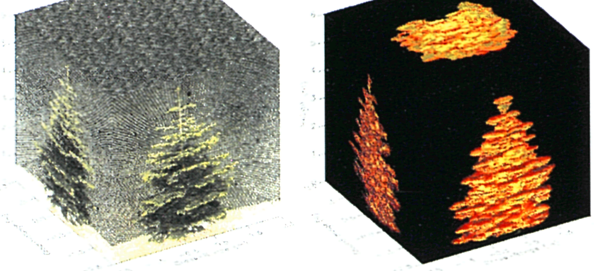


Figure 6.4 : The three-dimensional radar response of a fir tree.

Tree-Scattering Experiments

The tree-scattering experiments were successfully realised in collaboration with the research partners from the George Washington University and from the Canada Centre for Remote Sensing. The experiment series performed at the EMSL with monostatic, bistatic and forward scattering measurements was aimed to study the scattering and attenuation properties of trees in the 1 - 10 GHz frequency band. A series of backscatter and bistatic measurements have been made on a 5 meter fir tree and a 2 meter spruce tree. In parallel to the microwave measurements accurate dielectric measurements of the trunk, branches and needles of these trees have been carried out and the geometry of each tree has been carefully measured.

The data set is ideally suited to test microwave forest backscatter models and forward scatter attenuation algorithms. Development of such a model are in progress at George Washington University; a three dimensional computer model for the reconstruction of the tree's physical structure is at work by the research partners in Canada. At the EMSL, based on this data a new investigation approach was implemented by reconstructing the three-dimensional radar response of the tree (shown in Figure 6.5) by means of a microwave tomographic technique.

Internal Research

- An adaptive algorithm especially tailored for subsurface radar imaging was developed and validated experimentally using EMSL data. In this validation, nine metallic dihedrals buried in three types of rocky soil were successfully detected using this technique. The resulting 3-D image showed a high signal to clutter level as well as a low geometric distortion.

- A new near-field 3-D inverse SAR processor was developed and successfully validated using both synthetic and measurement data acquired in the EMSL. The focusing algorithm makes use of the stationary phase method and has been highly optimized reducing the computation times by a factor of 5, compared to an standard algorithm using Fast Fourier Transforms. A 3-D radar image of dimensions 5x5x5 m^3 with a spatial resolution of about 10 cm was computed. The target (Figure 6.4) was a 5 m high fir tree which was measured with 24 deg of angular span in azimuth and elevation.

This measurement was fully polarimetric and the frequency ranged from 1 to 5 GHz.

- A measurement showing the use of ultra-wideband radar interferometry for remote sensing of structural deformation was carried out. As a result, a high accuracy map of the global deformation of a target consisting of two parallel concrete bars was obtained (Figure 6.5). Displacements ranging from centimetres down to fractions of a milimetre were measured in the interferograms.

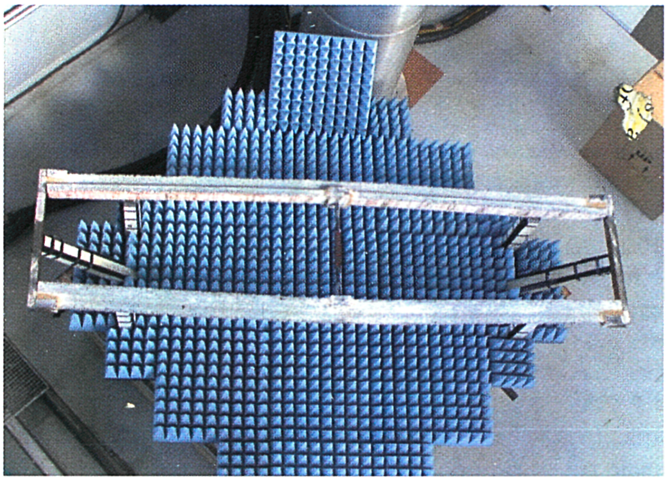


Figure 6.5a : The experimental setup.

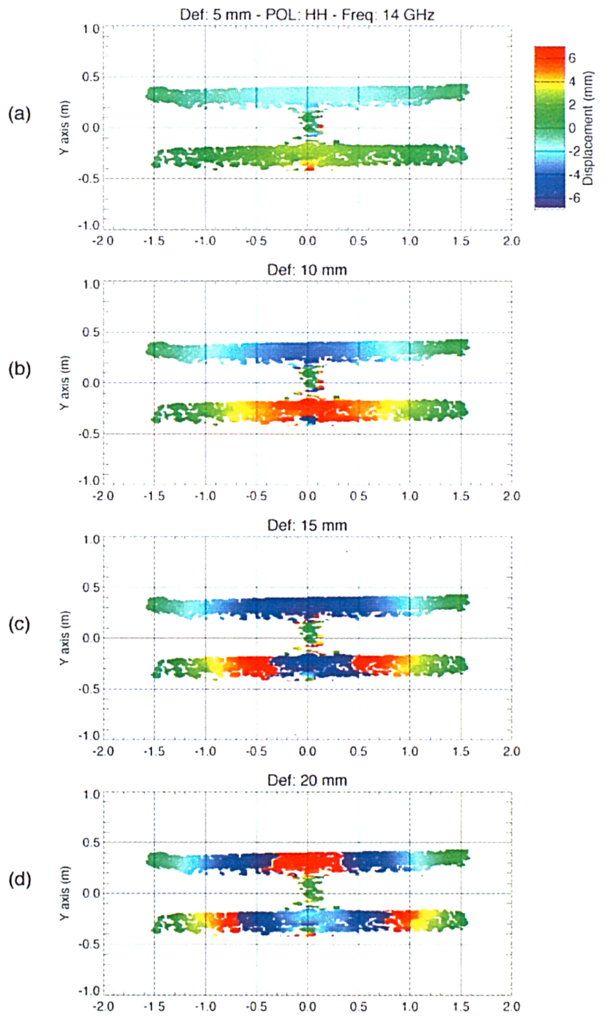


Figure 6.5b : SAR interferograms showing distortion maps of two parallel concrete bars subject to driving force in the centre.

Third Party Work

- Surface Scattering Tests on Asphalt Road Samples, Contract No. (11310-95-10T1PC ISP D), performed for Daimler Benz Research Center Ulm, Germany: Preparation and test conditioning of different asphalt road targets for radar measurements with mobile sensor arrangement. This work was a follow-up of the RoCoCo project. The contract was signed in November 1995 and completed in February 1996.
- Radar Cross Section Measurements of Cars, Contract No. (12146-96-08 TIPC ISP D), performed for Daimler Benz, Stuttgart, Germany: Measurement of the Radar Response of six different cars in the EMSL. Contract signed in August 1996, completed in December 1996. A systematic representation of one car is shown in Figure 6.6.
- RADET Project, Contract No. (1782-96-04 T1PC ISPI), commissioned for ESA by Officine Galileo, Italy: Radiometric measurements with a rain simulation experiment. Contract signed in January 1996, execution delayed due to test specification problems, foreseen performing in April-June 1997.

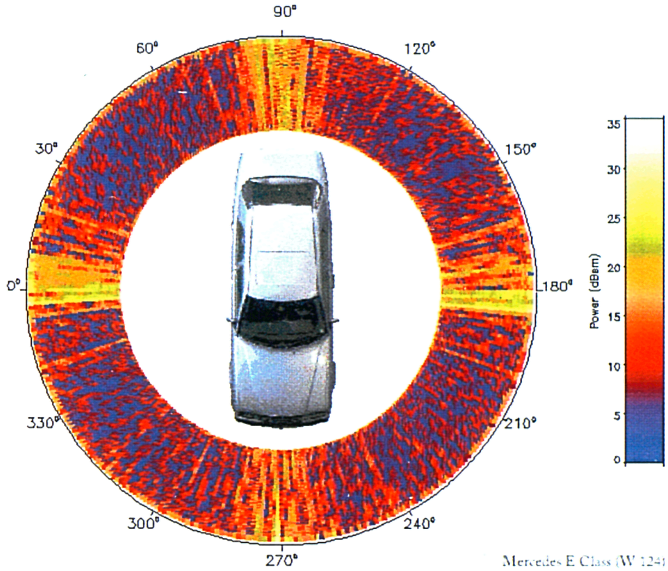


Figure 6.6 : The radar response of a car vs. Frequency and azimuth aspect angle at a frequency of 76 - 77 GHz, with HH Polarisation.

Competitive Support Activities

- Dissemination of EMSL radar signature reference data, CSA project with DGXIII/D1, (CSA95E1): Started January 1996, completed January 1997.
  The DGXIII, in the frame of the Value Programme was ready to fund the development of a dissemination tool for the EMSL experimental Radar Signature Reference data (RSR). The project was executed by an Informatics Engineering firm under the co-ordination and scientific guidance of the EMSL staff. The objective was to set up a "RSR Packaging System", an informatic tool allowing the generation of RSR packages from the EMSL data archive and to write the package on a CD-ROM for distribution to external user.
  With this system the first RSR Package of EMSL dealing with "Radar Imaging Techniques" has been created; in January 1997 this prototype package was ready for distribution on CD-ROM medium.
- Dissemination Network for EMSL Data and Processing Capabilities, Competitive Support Activity for DGXIII/D1, project CSA96P26: Signed in November 1996, to be started in January 1997.
  As further step in the data dissemination process at the EMSL this project aims to implement a Network Information Server to give access via Internet to a public area in the EMSL data archive

Theoretical Modelling

In the framework of a collaboration with the Polytechnic University of Valencia, Spain, an efficient and complete electromagnetic scattering model for tree trunks above a tilted rough ground plane was developed. Results have been computed for the mean square error of the bistatic scattering pattern averaged through 50 realisations, by means of a Monte-Carlo simulation. The developed method allows a wide set of simulations in order to characterise vegetation cover and to determine the sensitivity of a number of variables.

The 1st EMSL User Workshop

About 50 experts from EU countries as well as from Israel, USA and Ukraine met at this workshop at the JRC Ispra on 23 and 24 April 1996. It was organised by the EMSL with three main aims:

- to provide a status report to the scientific and industrial user community after almost four years of operating this unique facility,
- to raise the visibility of the EMSL User Groups,
- to foster co-operation between scientists and with industrial customers.

The workshop's main objectives were important with regard to the request by the Board of Governors of the JRC and its Director General to submit proposals to EU Programmes, to create thematic networks, to support and diversify the EMSL activity and to fund access by external users.

The workshop sessions covered a wide range of topics including SAR imaging and interferometry, industrial applications of microwave sensors, scatter modelling and signal analysis. Further sessions were dedicated to the proposed European RTD programme on methods for searching for anti-personnel mines, and to the task force *"Car of Tomorrow"* of the European Commission.

In the discussions strong demand was expressed to set up a meeting place in Europe for the exchange of information on experimental microwave signature facilities and on new trends and applications. It was suggested a catalogue to be prepared of the existing facilities, mentioning the type of experiments done by each one, its performances and the resulting data and their format.

Setting up a formal European network was a further topic of the discussion, e.g. a network, centred around the unique features of the EMSL, to be submitted to the TMR program. The network will mainly address the scattering community and focus on the study of electromagnetic wave/target interaction, by stimulating new applications, implementing the necessary experiments at the EMSL, and making measurement data available through modern telecommunications means.

It was felt that short and long-term research must be well balanced. Short-term applied research seems to have priority for European funding, but future European competivity has to be safeguarded by longer-term research plans.

In summary, the participants, recommended that the EMSL continue its work programme which comprises on the one hand clear application-oriented tasks and on the other, more scientific aspects with regard to model validation, radar imaging, radar interferometry and the investigation of scattering mechanisms of natural and man-made targets. The EMSL was also asked to provide access to standard data sets, to develop such standards, and to provide the user community with a platform for exchange of information.

The Workshop proceedings are in two parts, one giving results of working with EMSL experiments and one ideas for new potential uses of this facility.

The EMSL Advisory Committee

In 1996 the Committee had two meetings in Ispra, on 24th June and on 22nd November. It provided independent views and recommendations on the annual operation plans, on the programme lines to follow and on the results of the research work and scientific activities of the EMSL team covering in-house studies as well as collaborative work with external institutes.

Some important topics addressed in the last meetings are summarised in the following:

- Research Policy. It was recommended that EMSL does work in its 'strong' fields, that means related to its "uniqueness", or to features like 'multi-static', 'full-polarimetric', 'large facility', etc.. Further selection criteria are e.g. to avoid to double work done elsewhere, to look for "usefulness" and "applicability" of results and to increase the part of third-party work.
- Application oriented research. It was recognised that basic research activities are essential for a proper expertise basis; but the main activities should be application oriented and programme lines have to be product oriented, even on expense of basic research. Due to the reduction of funding for basic and experimental research at the JRC, the EMSL is forced to look into new tasks in the application oriented research.
- Proposal priorities. The list of EMSL experiment proposals was evaluated by ranking the thematic topics with the following priorities: (1) Mine Signature Research, including subsurface imaging and polarimetric interferometry. (2) Differential Interferometry for detection and monitoring of changes applied to structural engineering or environmental scenarios. (3) Road Quality Testing, and (4) Vegetation Model Verification.
- EMSL Activity Plan. The thematic user group scheme of the past should not be continued. However, this should not exclude to form new thematic groups around experimental activities; but they must always find at the EMSL an internal scientific counterpart in order to continue progress and to gain expertise in the team.
- EMSL Experimental Data policy. The availability of EMSL data on the Web was recommended to stimulate other researchers to use this results.

Perspectives for 1997

The EMSL activities will follow two main lines: Mine Signature Research and Differential Interferometry, as recommended by the Advisory Committee. The investigations will include subsurface imaging and polarimetric interferometry as well as differential SAR interferometry for changes detection in engineering structures or environmental scenarios.
Third party work (ESA contract) will be performed with priority as well as the proposed Competitive Support Activity (Demonstration Exercise for deformation detection on large structures, DGXIII/D1 proposal) and the Cost Shared Action project (Materials Reflectivity Data Bank, DGXII proposal) when granted to the EMSL.

6.3

Advanced spectrometry

1996 PROGRAMME OF WORK

Summary of Objectives

- Performance of 1996 program of experiments in the European Goniometer EGO
- Improvement of the measurement capabilities of the EGO laboratory
- Continuation of signature research in the optical domain and, in particular, bidirectional reflectance measurements using EGO

1996 Milestones

January: Preparation of the first Workshop for the 1996 program of experiments in the European Goniometer EGO
February: First EGO Workshop held at JRC, Ispra with the participation of five external groups whose proposals had been selected in 1995 for experimental work in EGO.
March: Further improvements made to EGO facility in preparation of forthcoming experiments.
April: First project performed in EGO in collaboration with RSL/University of Zurich
May: First part of project performed in EGO in collaboration with the Observatory / University of Helsinki
June: Projects performed in EGO in collaboration with the University of Paris 7 and DLR / Berlin
July: Project performed in EGO in collaboration with NORUT Information Technology Ltd. / Norway
September: Installation and testing of recently acquired CCD camera for measurements in EGO. More testing of EGO illumination sources and detector stability.
October: Performance of second part of project in EGO in collaboration with the Observatory / University of Helsinki
November: Analysis and examination of some of the experimental data acquired during 1996 program of experiments
December: Preparation of further improvements to EGO Monitoring System software and first plans for possible experiments in 1997.

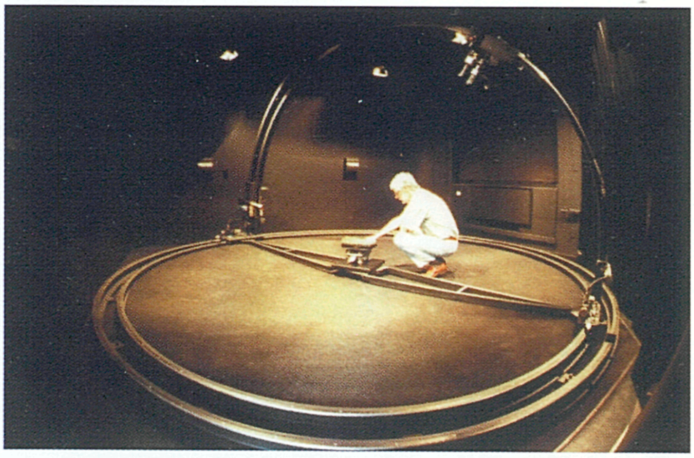


Figure 6.7 : The European Goniometer.

European Goniometer EGO

During 1996, several significant projects have been undertaken in collaboration with various European research institutes and universities. The projects were initiated in 1995 and finalised in a Workshop held at the JRC, Ispra in February 1996. Most of these projects involved the measurement of the bidirectional reflectance distribution function (BRDF) of natural and artificial targets of interest in Remote Sensing applications in the optical domain. The EGO Goniometer (Figure 6.7) is ideal for this kind of measurement and several different detectors (eg. spectroradiometers, CCD camera) and illumination sources (eg. collimated lamps and laser sources) available at EGO were used during the experiments. The individual projects are described below.

Besides the performance of experiments in the projects described, the EGO facility itself was the subject of various modifications and improvements. One such modification was the installation of a new cable support system which allows the system to operate freely and in such a way that the motor, illumination source and detector cables follow their respective sleds along the arcs without obstructing the sled movement. This modification has considerably improved the capabilities of the EGO system and most angular positions can now be pre-programmed without prior test runs. During the course of the experiments, many tests were also made to investigate the stability of the illumination sources and some improvements are planned for 1997. The positioning precision of the system

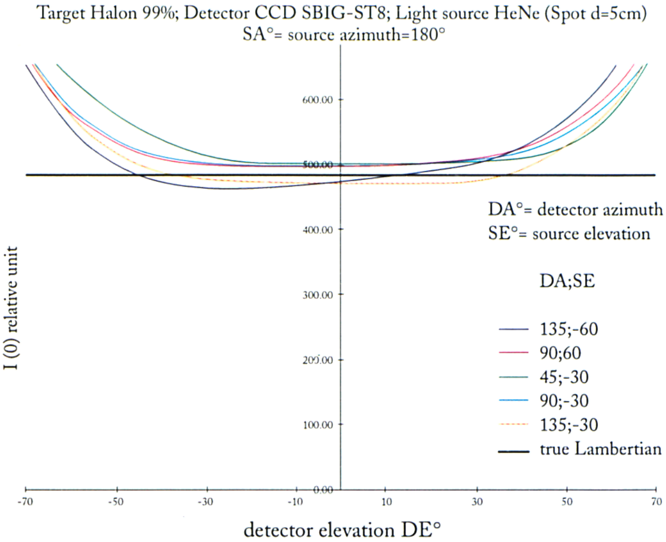


Figure 6.8 : Measurement of diffused light by means of the CCD camera.

itself was also verified and improvements to the mechanical supports of the detectors and light sources have been made continuously during the year based on the experience gained in the experiments.

As for the detectors available at EGO, the ASD FieldSpec radiometer was upgraded during 1996 by the manufacturer and the detector appears to have been significantly improved. Further tests on this detector in the EGO facility however are still required. One of the projects performed used mainly the recently acquired SBIG-ST8 CCD camera. This camera permits high resolution imaging of the various targets used in the system in the visible and near IR range and can be used as a general purpose detector. The camera is also equipped with a motorised filter wheel. By means of the CCD camera image, it is also possible to measure the light diffused by the target as shown in Figure 6.8. A new HeCd blue laser (442 nm) has been ordered which will add to the illumination sources currently available at EGO. This source should be tested and installed during 1997.

1996 EGO Projects Programme

Sensitivity Studies of Bidirectional Reflectance Data using the EGO/JRC Goniometer Facility

The first project to be carried out was designed by RSL, Department of Geography at the University of Zurich and used the GER-3700 spectroradiometer to test several experimental hypotheses in EGO on various targets of interest (Figure 6.9, target of cress). The EGO facility is of particular interest to this team from Zurich since a similar facility, the Field-Goniometer (FIGOS), exists at the University in Zurich for the performance of BRDF measurements. Thus it was possible to compare the two systems and to verify under laboratory conditions some experimental methods used in the field.

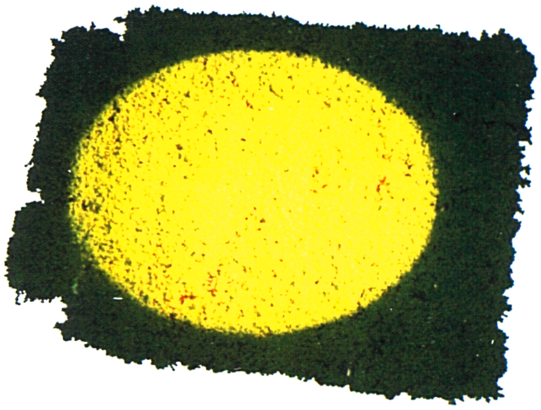


Figure 6.9 : A target of cress under the lamp.

Radiative Transfer in Random Media

The second project was designed by members of the Observatory of the University of Helsinki and involved the use of the high resolution SBIG-ST8 CCD camera mounted as detector in the EGO Goniometer. Specific targets of interest included Sahara sand, Titanium oxide and several qualities of paper of interest in the paper industry. A teflon mould (Figure 6.10) was machined at the Central Workshop of the JRC in September and used to produce rough surfaces with specific statistical parameters for some of these experiments. The statistical parameters were generated by a code used to create similar surfaces for experiments in the microwave signature laboratory EMSL.

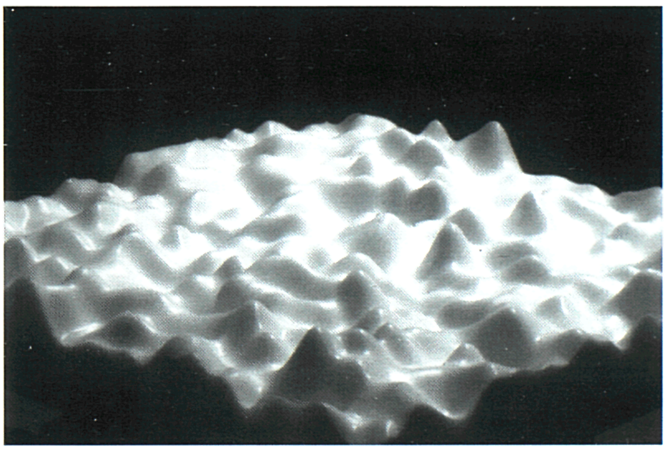


Figure 6.10 : The teflon mould produced at JRC.

Verification of Computer Simulated BRDF Models for Vegetative Surfaces

The third project was performed in collaboration with researchers from DLR, Institute for Space Sensor Technology, Berlin. This project was mainly focused on the BRDF of natural surfaces using targets such as clover (Figure 6.11) and other vegetative canopies. The measurements were made in the 400-1000 nm range using a high sensitivity Spectron Engineering SE590 spectroradiometer with 252 channels. The targets were prepared at the JRC, Ispra.

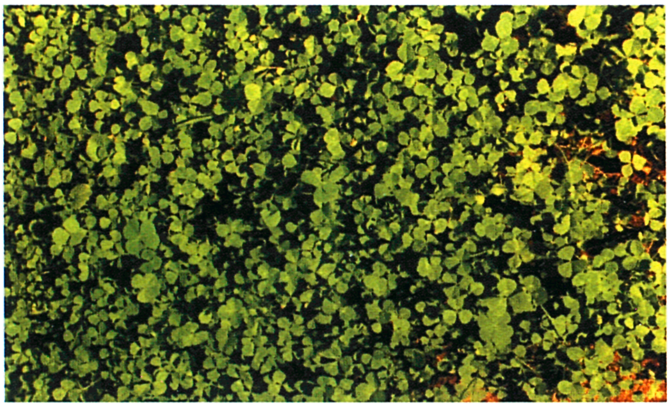


Figure 6.11 : A target of clover used in EGO.

Investigation of new Inversion Techniques to Extract Information on Vegetation Canopies

The fourth project was performed in collaboration with researchers from the Laboratoire Environnement et Developpement, Université de Paris 7. This project was mainly focused on the BRDF of artificial surfaces using targets made from specially prepared artificial plants with known characteristics (Figure 6.12). The measurements were also made in the 400-1000 nm range using the SE590 spectroradiometer.

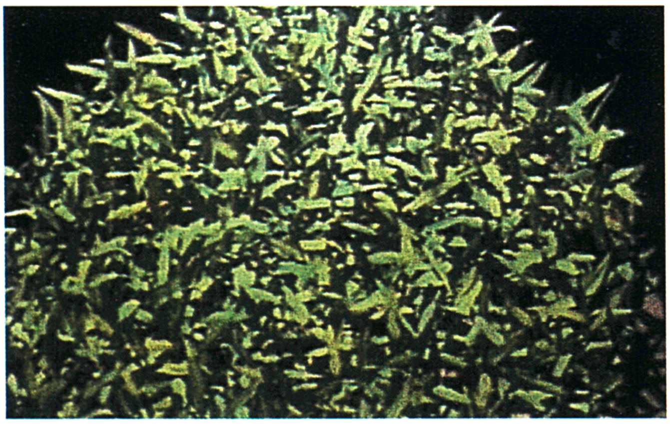


Figure 6.12 : The artificial plants used for BRDF measurements.

An experimental study of bidirectional reflectance properties of lichens

The fifth project was designed by NORUT Information Technology Ltd.(Tromso, Norway). This involved several series of BRDF measurements over different types of lichens (Figure 6.13) and moss typical of the sub-artic landscape. The lichens are important indicators of air pollution and are of particular interest in remote sensing applications at northern latitudes. The spectral range was 400 to 1000 nm as above and temperature and relative humidity of the targets was also monitored during the experiments with other detectors available at EGO. The resulting BRDF for one of these lichens is shown in 3D in Figure 6.14.

Figure 6.13 : Lichens as EGO target.

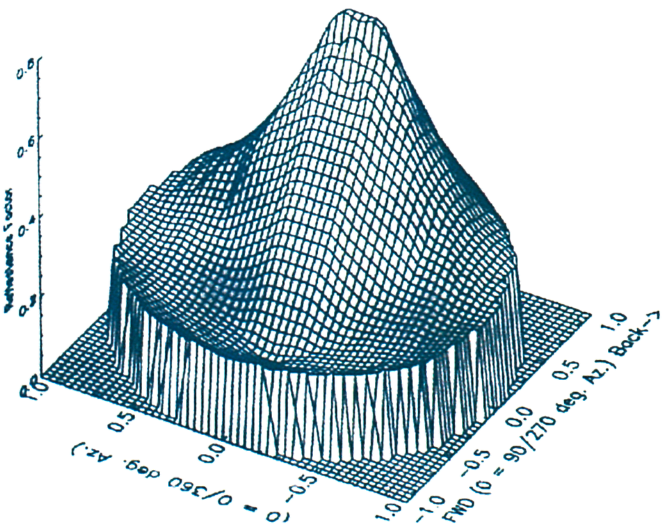


Figure 6.14 : The BRDF measurements from the lichens.

The experimental results obtained during these measurements in the Goniometer are currently being processed and analysed and the first conclusions can be expected in 1997. More details on the individual experiments are now available on Internet. The projects have made use of some of the possibilites offered by the EGO Goniometer at present and have also served to highlight particular problems which can arise during this kind of experiment which rely to a great extent on the precision required of the detectors, the stability of the illumination sources and the mechanical precision of the Goniometer itself. Each project also generates a large amount of data which have to be carefully checked and analysed in order to obtain a correct and significant result. At the end of this process, the results will be made available to the scientific community in general for further evaluation.

Perspectives for 1997

A second EGO Workshop is planned for early 1997 where the experimental results obtained in 1996 will be discussed in detail with the proponents and new projects considered.

Improvements in EGO illumination sources stability are to be carried out.

A new series of experiments in EGO is expected.

Further testing of recently acquired and current detectors and illumination sources in EGO will continue, and the existing EGO Monitoring System software will be upgraded based on 1996 experience.

Analysis, documentation and archiving of recent EGO experiment results and data will be carried out. This will also include further progress in realisation of operational EGO experimental data access via network.

Finally the year will see the preparation of publications relative to projects and experiments performed in EGO in 1996.

Centre for Earth Observation

The main objective of the CEO Programme is to increase the number of operational applications of Earth observation (EO) data from space. In order to achieve this, the CEO Programme seeks to increase the number of customers of EO derived information (in research, governmental and commercial fields), to encourage and stimulate the EO related industry (research and commercial) and to improve the access and availability of EO and related data, information and services.

Design and Implementation Phase

The Pathfinder phase of the CEO Programme was concluded at the end of 1995. Following the unanimous approval of the participating countries via the Pathfinder Phase Steering Committee, and the formal approval of the JRC's (Joint Research Centre) Board of Governors, the CEO Programme has now moved into the Design and Implementation Phase. This phase will take the Programme to the conclusion of the 4th Framework Programme at the end of 1998.

Activities

Four interrelated components have been identified as the basis for actions to meet the objectives of the Design and Implementation phase, namely Application Support, Enabling Services, User Support and Monitoring & Co-ordination. Many initiatives within these components were launched in 1996 and are expected to produce results towards the middle of 1997. These include the following:

User Support:
This set of activities aims to help the user benefit from Earth observation to meet his or her professional goal. User support thus includes initiatives on metadata standards, on a long-term European Digital Data Archive (EDDA) for Earth Observation, on an inventory of EO algorithms, models and software, on EO education resources and on market development for new customer segments of EO. A Helpdesk service was launched in 1996.

Monitoring & Co-ordination:
This activity will manage, co-ordinate and develop the Programme. Here, the CEO is currently in discussion with related international activities (such as NASA-EOSDIS, NOAA-GCDIS, CCRS-CEOnet), European data providers (such as ESA, EUMETSAT, SPOT, EURIMAGE), as well as national initiatives within Europe, such as NEONET in the Netherlands and ISIS in Germany, regarding collaboration and joint working agreements. The programme has also made significant contributions to CEOS (Committee on Earth Observation Satellites) and G7 initiatives on the accessibility and availability of data and information, as well as progress towards an agreed international catalogue interoperability protocol (CIP).

Application Support:
This activity aims to stimulate the production of information from Earth observation data in response to customers needs and to attract more customers to EO. Within this component, the CEO Programme is encouraging the development of EO applications by shared-cost funding of appropriate projects. These include the Calls for Proposals issued by DGXII of the European Commission, under Area 3.3 (Space techniques applied to environmental monitoring and research) of the Environment and Climate Specific programme, and a number of projects in support of the Services of the Commission. Actions to make data sets accessible were also started during 1996, including those of ECMWF.

Enabling Services:

Through the Enabling Services, the CEO provides the software tools and systems to increase the exchange and accessibility of metadata about EO. The CEO is already operating a prototype information server on the Internet, the European Wide Service Exchange (EWSE) and the G7 ENRM virtual library. These are described in greater detail later.

The diagram below illustrates how these components are closely related to each other to form a coherent programme.

Documentation describing all these activities in full is available via the CEO on-line services at the following address: http://ewse.ceo.org/anonymous/library/ceodocs.pl.

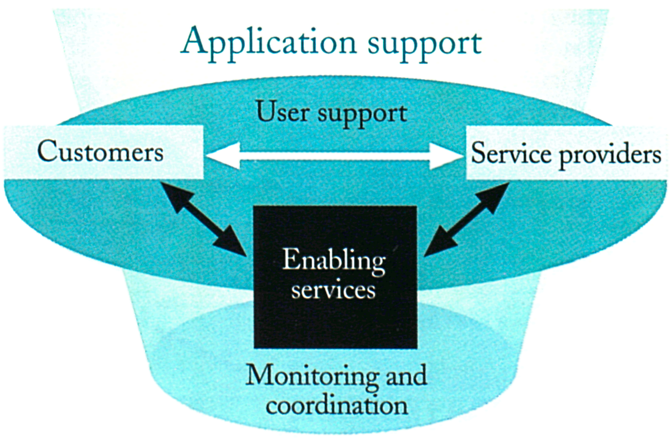


Figure 7.1 : The interrelated components of the CEO Programme.

7.1

Design and Implementation Phase Activities

1996 PROGRAMME OF WORK

Summary of objectives

To design and implement the CEO Programme, and in so doing to:

- programmes, commercial companies, governmental institutions) operationally using information derived from Earth observation data
- help to ensure that there is a service provider industry (research and commercial) that is capable of operationally providing the services that customers require
- make EO related data, information and services more available and accessible

1996 milestones

- CEO Officially Moves Into The Design And Implementation Phase
- Programme is reviewed by DISC (Design and Implementation Steering Committee) in Jun. 96 and Dec. 96
- The Enabling Services (an EO data and information system on the Internet) has been designed and the construction has now began
- New potential customers of EO are being targeted through a series of customer workshops
- A database showing proven EO applications and their customers has been compiled
- In co-operation with DGXII D4, 18 application development projects have been selected for shared cost funding, as well as 2 concerted actions on European level subjects
- CEO launches application projects in support of the EC services

CEO Officially Moves Into The Design And Implementation Phase

At its June meeting the JRC's Board of Governors (made up of representatives of the Member States) formally approved that the CEO programme should move from the Pathfinder Phase to the Design and Implementation phase. This follows the unanimous approval of the Pathfinder Phase Steering Committee (participating State delegates nominated by the Board of Governors to monitor the progress of the programme) at their eighth meeting in December 1995.

Design and Implementation Phase Steering Committee

The CEO is advised by a committee composed of delegates of the 16 countries who participate in the CEO programme (European Union plus European Economic Area countries). It is also observed by a number of relevant European organisations, including ESA, EUMETSAT, SPOT Image, Eurimage, The European Environment Agency, EUMETSAT and the European Association of Remote Sensing Companies (EARSC). This committee, entitled the Design and Implementation phase Steering Committee (DISC), has been nominated by the Joint Research Centre's Board of Governors, and by the Management Committee of the Environment and Climate Specific Programme (COPEC) to advise the European Commission on the direction of the CEO programme, and to ensure that the CEO is in line with national requirements.
DISC met for the first time on the 10th-11th June in Brussels to review the status of the CEO programme. It noted that it was happy with progress, and encouraged the CEO Team to proceed along the lines set out in its Plan for the Design and Implementation phase. DISC met again on the 10th-11th December.

Design and Implementation of the CEO Enabling Services started

The architecture of the CEO´s next generation Enabling Services was finalised in the first part of 1996. It will provide European EO Users with a *"one-stop shopping"* facility that will be an easy-to-use system for querying data repositories on geographic, thematic, sensor or temporal subjects.

It has been designed such that, although the databases are located in various places across Europe (or even the world), it will be perceived by its users as one integrated system. The data and information will in reality be held by individual service providers at various locations throughout Europe. It is envisaged that this will be achieved by means of a number of Middleware Nodes (MWND). These will hold the functionality to allow customers to search for the data, information and services they need, and will allow catalogue owners, service providers, commercial, public and research organisations to announce and advertise their data, information and services. This is schematically illustrated in Figure 7.2 below.

The Enabling Services (ES) of the CEO programme will be built by European industry. A tender procedure was initiated in June 1996 splitting the work into 6 main contracts to build the basic modules constituting the Middleware Node and the Monitoring and Co-ordination Facility. The implementation work was split in the following categories:

1. Implementation of the search sub-system
2. Implementation of the announcement and advert sub-system
3. Implementation of the reporting and monitoring sub-systems
4. Implementation of the data dictionary and user profile sub-systems
5. Implementation of the on-line help, help desk and newsgroup sub-systems
6. Integration of subsystems 1-5 and testing.

In total, the proposals received in response to these Invitations to Tender (ITTs) weighed over 10 tons! Preparatory kick-off meetings were held with the successful consortia during mid December 1996. The implementation of the Enabling Services will follow a phased approach. The first release of the Enabling Services (Release A) will be constituted by one Middleware Node, one Monitoring and Coordination Facility and the User Support Facility. It will be on-line by the end of February 1998. Release B will support a configuration with multiple Middleware Nodes and is foreseen to be available by the end of 1998.

Customer Workshops for the CEO

In a bid to expand the market for EO data and information, the CEO issued an Invitation to Tender (ITT) during 1996 for the study of specific customer groups. Each study will conduct a series of workshops with the customer group, aiming to understand the tasks undertaken by the potential customer and then determine where EO information can be of value. As a first step, five specialised customer segments have been chosen as the subject of these studies, viz. insurance companies, the travel and tourism industry, environmental protection organisations for land resources, town/city local government departments and civil engineering companies.
The project kick-off meetings were held during November 1996 and the contracts should be concluded by the end of May 1997. The final reports of each of these ITTs will be made publicly available via the EWSE. The contractors will produce a briefing paper aimed at their specific customer segment and these will be widely distributed to appropriate organisations.

Demonstration Case studies

The CEO intends to attract new customers to EO by demonstrating how EO data and information can effectively be used in a wide variety of application areas. Following two calls for such demonstration case studies, the CEO has compiled a library of approximately 140 operational or near operational examples from organisations currently using remote sensing data. Each example contains information on costs and previous customers, in order to help a new potential customer to rapidly assess the benefit or otherwise of EO to his or her needs.

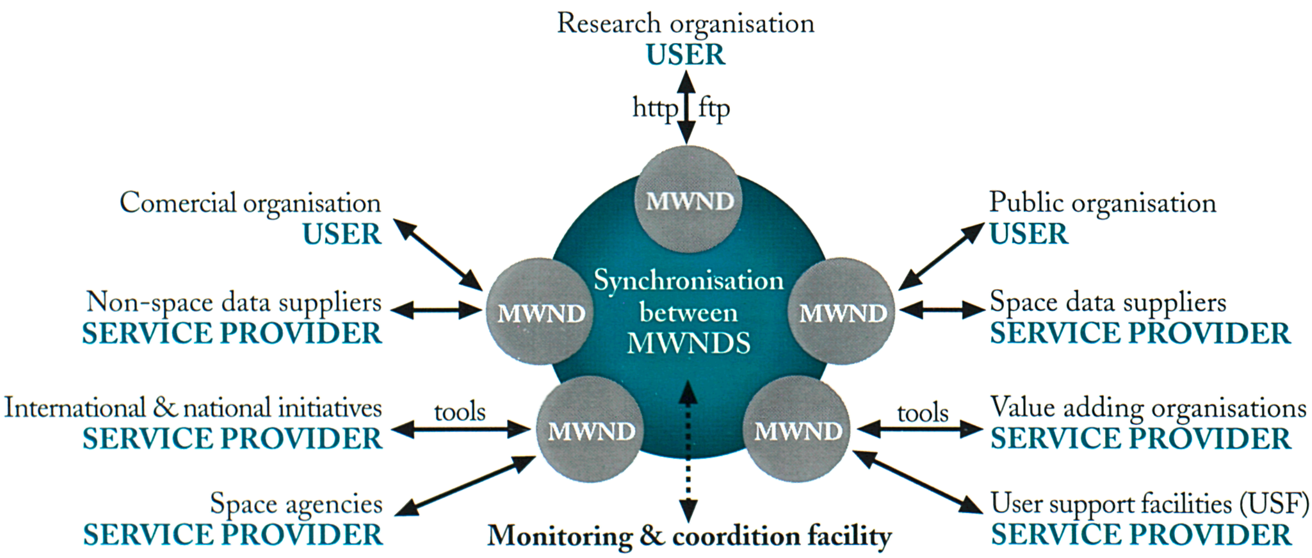


Figure 7.2 : Architectural Scheme of future Enabling Services of the CEO.

These have made available on the Internet via the EWSE. They cover a broad range of thematic areas such as agriculture, cartography, civil planning, coastal, education, environment, forestry, geology, hydrology, ocean weather, oceanography and urban.

Call for Proposals for Area 3.3 (CEO) of the Specific Programme for Climate and Environment

The CEO Programme is undertaking thematic projects funded under the 4th Framework Programme of DG XII. Specifically, these projects come under Area 3, Space techniques applied to environmental monitoring and research, of the RTD (Research and Technological Development) programme in the field of Environment and Climate.

These projects, termed shared cost actions since the Commission will fund up to 50% of the cost, will be innovative in nature and demonstrate how EO information can be introduced into the professional tasks of specified customers who will be centrally involved in the project. Spin-offs from such research, e.g. information on metadata-data, expertise, algorithms or the actual production of a high level product, will benefit other users of the CEO.

The first Call for Proposals for these shared cost action projects was completed during 1996 and the CEO has received many applications from a broad range of thematic areas. The results of the evaluation of these proposals will be made known once all the contracts have been finalised. A second Call for Proposals will be released in 1997.

CEO launches application projects in support of EC Services

The CEO supports a number of application projects with the aim to demonstrate the usefulness of remote sensing to satisfy information needs within the Services of the European Commission. Although the Commission is the largest single civilian user of remote sensing data in Europe today, particularly for the purpose of agricultural monitoring, there are still many other areas where remote sensing could be applied to collect information for defining, implementing or monitoring of Commission policies. These include areas such as regional development, environmental monitoring, fisheries or external economic cooperation.

To date, five projects have been defined. They are currently in the definition and/or implementation phase and are expected to run until the end of 1998. The projects are funded by CEO and technically carried out by the thematic Units of the Space Applications Institute of the JRC.

These projects and their respective customer at the Commission are shown in Table 7.1 below.

Perspectives for 1997

The bulk of work on the implementation of the Enabling Services will be carried out during 1997, with the first version being released in early 1998. The results of the five Customer workshops will be made publicly available on the EWSE. The CEO plans to bring out a CD-ROM with all the Demonstration case studies for those users without an Internet connection. A second Call for Proposals for Area 3.3 (CEO) of the Specific Programme for Climate and Environment will be opened. The CEO recommendations on the description of EO data, services and information (i.e. metadata) will be published in early 1997, and work will continue on EO catalogue interoperability. The projects in support of the Services of the Commission that were kicked off in 1996, will produce their first results during 1997.

The CEO Programme will launch an ITT for the development of EO in education and training at the start of 1997, as well as ones for new market segment studies and an inventory of products and services.

Project acronym	Thematic area	Customer EC service
LACOAST	Land cover changes in European coastal areas	DGXI, EEA
SEARRI	Monitoring of agriculture (wetland rice paddies) in SE Asia	DGIB, DGVI
FMERS	Forest monitoring in Europe with remote sensing	DGVI
ATLAS	Statistical analysis of urban agglomerations in Europe	DGXVI, EUROSTAT
DESIMA	Decision support system for coastal areas	DGIB

Table 7.1 : Projects and their respective customer at the Commission.

7.2

Information services offered by the CEO

1996 PROGRAMME OF WORK

Summary of objectives

To offer on-line services that will help to make EO and related data, information and services more available and accessible

1996 Milestones

Mars: Launch of CEO WWW site

May: Launch of CEO Helpdesk

June: Number of user registrations on the EWSE exceeds 1000

Launch of G7 ENRM virtual library on the Internet

November: Launch of CEO's Fax on Demand and Fax Broadcasting system

December:
Launch of 3 IMS Gateways on EWSE

CEO WWW site

The CEO Programme has introduced a number of on-line information services for a variety of reasons; firstly to improve accessibility to EO data and information, secondly to provide users with information about the Programme, and lastly, but by no means least, to keep abreast of technology developments on the Internet. Presently, the Programme offers a CEO Programme Internet site, a CEO Helpdesk service, a Fax on Demand service, and two information exchange systems, the EWSE and G7 ENRM servers.

In March 1996, the CEO Programme launched a new WWW site dedicated to providing information about the programme and its activities, CEO documents, the CEO team members and any announcements or events related to the CEO and its information service, the EWSE. This WWW site can be found at http://www.ceo.org/.

CEO Helpdesk Service

From 1st May 1996, CEO offered an operational Helpdesk Service where two types of services are offered:

- CEO Help! deals with general inquiries related to the CEO programme.
- EWSE Help ! deals with inquiries related to the use of the European Wide Service Exchange (EWSE).

Inquiries can be submitted to the Helpdesk in written form, either by e-mail, fax or postal mail, and will be answered or acknowledged within one working day.
The contact points are:

- CEO Help!: e-mail: ceo.helpdesk@jrc.it;
  Fax: +39-332-78-5461; Post: EC JRC, SAI-CEO, TP441, 21020 Ispra (VA), Italy.
- EWSE Help!: e-mail: ewse-admin@jrc.it;
  address & fax as for CEO Helpdesk.

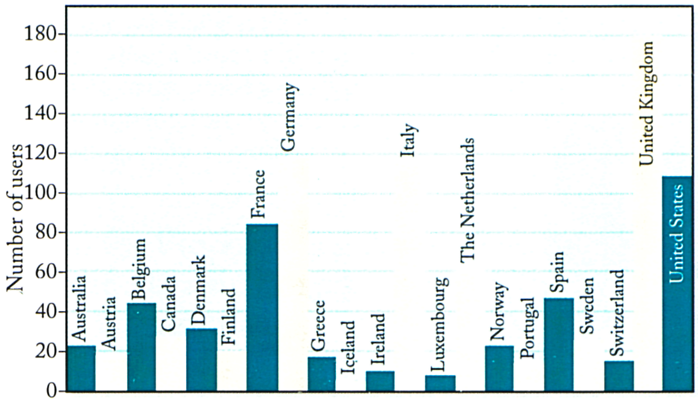


Figure 7.3 : The number of registered EWSE users by country in December 1996.

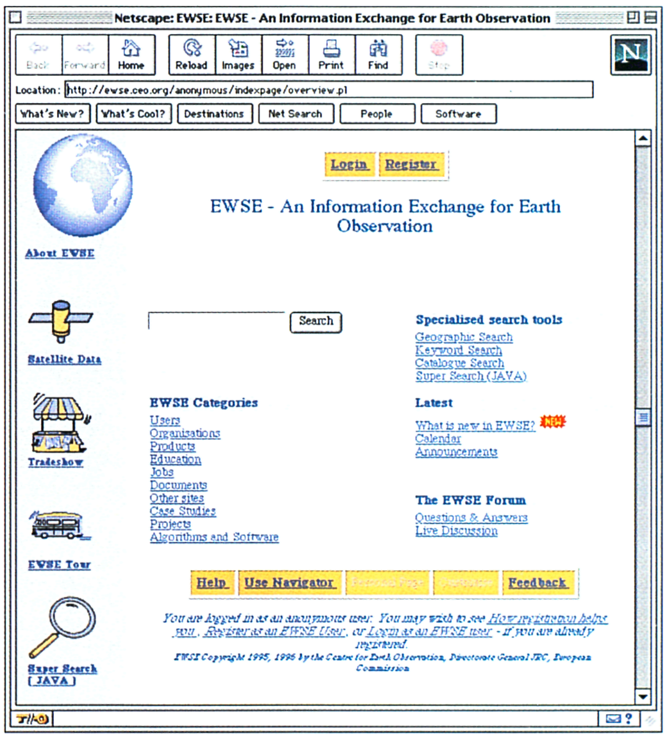
The European Wide Service Exchange (EWSE)

In 1995 the CEO team developed an EO data and information exchange system, named the European Wide Service Exchange (EWSE) which became operational in September of that year. The EWSE is based on the Internet and can be found at http://ewse.ceo.org/.
Since then over 1200 users from 47 different countries have registered on the EWSE. The majority are from Europe, but a significant number of contributions are from the USA, Canada and Australia (see Fig. 7.3).
The EWSE also offers over 500 resources, encompassing EO organisations, EO products and services, and EO case studies. Searches for information on the EWSE can be carried out in a number of different ways: by free text, by keyword or by location (on the map of the globe). Organisations or individual users, registered with the EWSE, can also be found via alphabetical lists or via the Tradeshow, where organisations are arranged by thematic area.

Since its release, the EWSE has continually been improved and updated. Version 4 of the EWSE went live towards the end of 1996. In this version, the EWSE was redesigned to offer faster loading via new text buttons and restructured to make it easier to use. The ënew lookí EWSE home page is shown at the right.

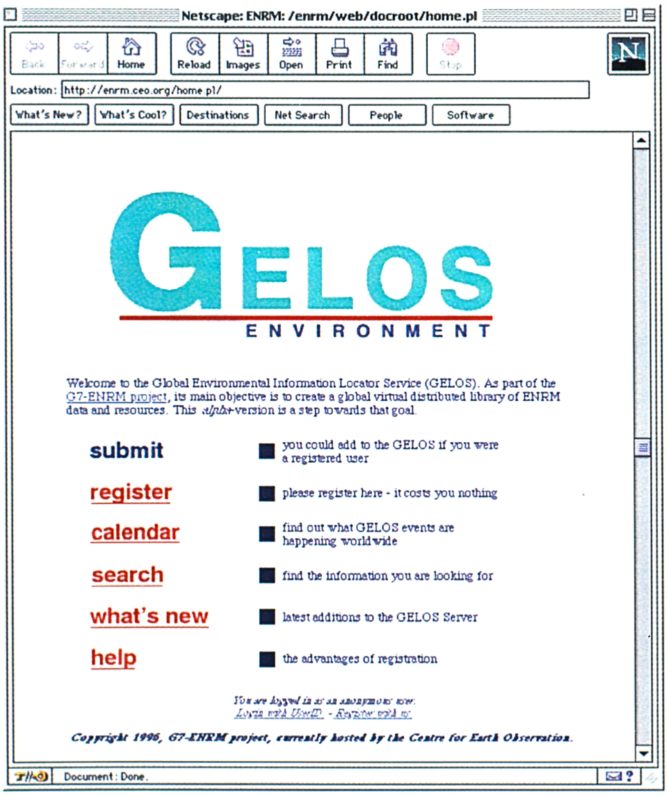
In addition, it includes some new features:

- The EWSE free text search has now an advanced search interface using a remote sensing thesaurus to expand queries and provide more flexible searching.
- A Java Navigator has been included. This is an optional feature which appears as a separate window for easy navigation through the EWSE.
- RS Newsgroups and Mailing lists. The EWSE now hosts 3 relevant newsgroups and 2 mailing lists dedicated to remote sensing topics. These are fully integrated into the EWSE and, as such, are included in any free text search operation.
- A Question and Answer service. This represents an interactive user forum on the EWSE. Registered users can now post questions and can respond to those posted by others.
- A collection of more than 140 case studies will be on-line by the end of 1996. These case studies demonstrate real applications of EO data and information in a wide range of thematic areas.
- Registered users can subscribe to an automatic e-mail broadcast to keep them abreast of *"What's new"* on the EWSE.
- The EWSE also offers access to 3 gateways for searching remote EO catalogues which support the IMS (Information Management System) protocol, one of which is the NASA gateway.



The G7 ENRM Virtual Library

Based on the model of the EWSE, the CEO team developed the G7 ENRM (Environment and Natural Resources Management) server. This represents part of the activity of the G7 Environment and Natural Resources Management (ENRM) Meta Information Topic Working Group (MI TWG), in which the CEO is involved together with the European Environment Agency (EEA).
This server is a prototype of a globally distributed virtual library of environmental resources. The most interesting feature of this server is its ability to "populate" its database by users world-wide who just have a normal Internet connection. The users' database entry can be updated or modified by him/her at any time, thus allowing to create an up-to-date database by a global user community. It also offers the user the functionality of searching the database in a variety of ways. The ENRM server can be found on the Internet at http://enrm.ceo.org/.



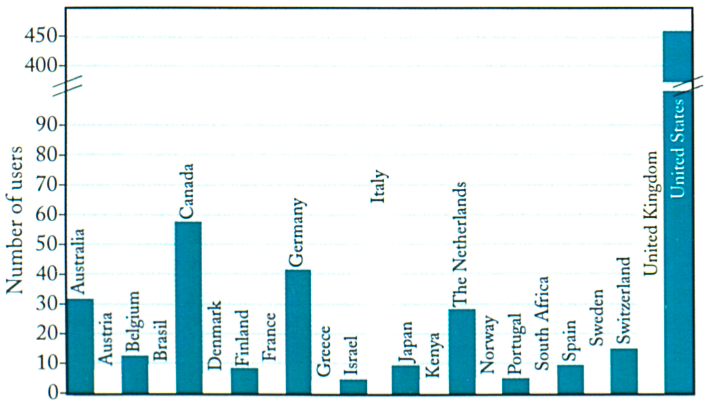


Figure 7.4 : Number of registered ENRM users by country in December 1996.

It has been a huge success with the registration of over 1100 users and 800 resources since its launch in July 1996. This represents users from 50 countries world-wide. The countries with the largest number of users are shown in Fig. 7.4.

This G7 ENRM server represents the first of the so-called Customised Information Servers (CIS) developed by the CEO for an external organisation. Other, non-space related organisations and programmes have also expressed their interest in taking advantage of the novel technical features of the EWSE and adapting this technology for their own purpose, as was done for the G7 ENRM server.
The CEO has thus agreed to develop a generic software code, based on the technology of the EWSE, which may be customised by the recipient host organisation according to its own specifications. A notable advantage of this will be that these CIS will use the same meta-information standards and interoperability protocols as the future Enabling Services. This will make searches possible among different CIS, as well as full searching of these by users using the EWSE / Enabling Services.

During 1996 the CEO was also involved in the development of a second CIS, the CEOS Information Locator Service (CILS) for CEOS (Committee on Earth Observation Satellites, U.S.A.) managed by the DLR in Germany, and funded by DARA. Work on this particular CIS will continue in 1997. The possibility of other CIS are under discussion with GCOS/GTOS/GOOS (Global Climate/Terrestrial/Ocean Observing System/s), EARSeL, and others.

New Fax on Demand service

As of 1 November 1996, the CEO offers a Fax on Demand Service, which will allow people to retrieve CEO documents without the need for an Internet connection. This service is available around the clock on fax number +39 332 78 5269. Instructions of usage can be obtained by phoning this number and selecting document number 1010. A list of available CEO documents is given in document 1000.

The CEO also offers a novel document broadcasting service, whereby selected documents will automatically be sent (by fax) to subscribers as they become available. These include announcements of contract opportunities (e.g. Invitations to Tender and Calls for Proposals) and the latest issue of the CEO Newsletter. The CEO offers both these services free of charge.

Perspectives for 1997

The efforts to ensure population of our information exchange systems, the EWSE and ENRM, will stepped up during 1997. Work will continue on the development of further Customised Information Systems. The CEO plans to launch an EO Helpdesk during the course of 1997 which will deal with any inquiry related to Earth observation.

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